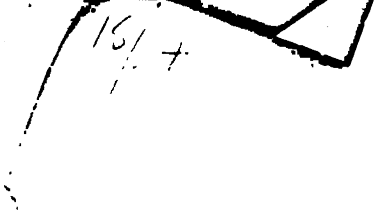
EWBIGGING'S

HANDBOOK FOR GAS ENGINEERS AND MANAGERS.

THE

GAS MANAGER'S HANDBOOK.

SIXTH (AND CENTENARY) EDITION.



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WILLIAM MURDOCH

INVENTOR OF GAS LIGHTING

HANDBOOK

FOR

GAS ENGINEERS

AND

MANAGERS.

BY

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Member of the Institution of Civil Engineers.

SIXTH (AND CENTENARY) EDITION, ILLUSTRATED.

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PREFACE

TO THE

SIXTH (AND CENTENARY) EDITION.

The constant advances that are being made in the Gas Industry have necessitated the addition of much new matter to the present Edition of the Handbook. To make room for this, without increasing the bulk of the volume, I have left out most of the coal testing results that were given in previous Editions. Some of these had become obsolete.

Much of the text has been re-written, and its arrangement and classification simplified and otherwise improved.

I have adhered, wherever possible, to my original plan of dividing the text into short paragraphs, with the object of assisting the memory and allowing of easy reference.

T. N.

5, Norfolk Street,
Manchester,
August, 1898.

PRINCIPAL CONTENTS.

[*For Alphabetical Index, see end.*]

ILLUSTRATIONS.

ERRATA.

Page 229, line 2 from bottom—

for $\left(\sqrt{\frac{h\,d}{s\,l}} = \frac{12}{\cdot 4 \times 1250}\right) = \cdot 024$, *read* $\sqrt{\frac{h\,d}{s\,l}} = \sqrt{\frac{12}{\cdot 4 \times 1250}} = \sqrt{\cdot 024}$

Page 324, line 14 from top, *for* 6·692 inches *read* ·6692 inches.

" 407, " 20 from top, *for* CaO_2, MNO_2 *read* CaO_2, MnO_2.

" 451, bottom line, *read* $\sqrt{(8 \times \text{weight to be raised})}$.

" 456, line 10 from top, Load of unhewn timber = 40 cubic feet.

" 468, " 8 from bottom, *for* $\sqrt[3]{\frac{20 \times 12}{30}} = 2$, *read* $\sqrt[3]{\frac{20 \times 12}{30}} = 2$.

NEWBIGGING'S HANDBOOK

FOR

GAS ENGINEERS AND MANAGERS.

COAL GAS.

INTRODUCTION.

THE art of coal gas manufacture is just about a century old. Between 1792 and 1798, William Murdoch, its inventor, was engaged, first at Redruth in Cornwall, then at Old Cumnock in Ayrshire, and finally at Birmingham, in experimenting with different coals, and in devising apparatus for their distillation.

In 1797-8 lighting by coal gas became an accomplished fact, for Murdoch, by means of his experimental plant, first lit up his dwelling-house at Old Cumnock with the new illuminant, and, on his removal to Birmingham in the latter year, having erected an apparatus on a considerable scale, he lighted a portion of the premises of Boulton, Watt, & Co., Soho.

The circumstance that coal would yield an illuminating gas was known long before that time. Natural gas, as it was found to issue from the bowels of the earth in particular districts where coal deposits existed, had been the subject of frequent observation, and its lighting power proved by actual trial; but no practical application was made of the knowledge till Murdoch bent his mind to the study of the subject.

A century is a long time in the history of an industry—longer than one exactly realizes at a first glance. The lapse of so many years since the discovery and application of gas-lighting confers something of the venerableness of age to the art. This is more obvious when cognisance is taken of the initiation of other arts, and the advances which

have been made in them, and not less so in the progress of the sciences, within that period of time.

Take railways for example. As compared with these, gas-lighting is old, for it had a start in life of thirty years before them. Nay, even the steam engine: that is no older than the art of gas-lighting, and much of its initiation and perfecting was due to the same fertile brain, for Murdoch was Watt's right-hand man at Soho, and invented the D slide-valve, the "sun and planet" motion, and the oscillating steam cylinder. As for the telegraph, the telephone, and electric lighting, these are but of yesterday—the younger sisters of the useful arts. Even the science of chemistry was only emerging from its swaddling clothes when gas-lighting was invented.

Although Murdoch had thus realized his dream of employing the gas produced from coal as a lighting medium, there was still much to be done to render the new illuminant acceptable. The impurities in the crude gas were found to be many and objectionable, and means and appliances for their elimination had to be devised. Suitable pipes for the conveyance of the gas to the point of combustion were also required. Murdoch devoted much time and effort in these directions, "washing the gas with water, and employing other means to purify it," and using tinned-copper and iron tubes for its distribution.

Other ingenious minds were early at work in the promising field thus opened out to the labourer. Lebon in France; Winsor at Frankfort, and later in London, where he projected "The National Light and Heat Company," which was afterwards incorporated by Royal Charter as "The Chartered Gaslight and Coke Company." Samuel Clegg, who had been a pupil or apprentice at the Soho Works, Birmingham; Dr. Henry, of Manchester; Northern, of Leeds; Pemberton, of Birmingham; John Malam; Samuel Crosley and T. S. Peckston, of London; Reuben Phillips, of Exeter; and Melville, of Newport, Rhode Island, U.S.A.

Chief amongst these pioneers was Samuel Clegg, who possessed a rare mechanical skill, combined with much shrewd common-sense. In 1805 he began to apply himself to the invention and construction of gas apparatus, and introduced the new method of illumination into many large establishments in different parts of the country. Clegg invented the hydraulic main, and the lime purifier as a separate vessel, though Mr. (afterwards Dr.) William Henry, of Manchester, the distinguished chemist, was the first to suggest the use of lime as a

purifying medium. Clegg also invented the wet gas meter, and evinced infinite resource in improving the apparatus of the gas factory in every department.

In these respects he was ably seconded by John Malam, who now stepped in and perfected the meter in such a way as to render it one of the most ingenious measuring appliances of this or any past age. The arrangement of four purifiers, which, with the centre valve, holds the field to this day, was also the product of Malam's ingenuity.

The new art of gas-lighting was fortunate in many of these its early exponents.

The "Chartered" vessel, launched by Winsor and others associated with him, floundered about for a while in a troubled, and, at times, a boisterous sea, due, no doubt, to the inexperience, but largely also to the incompetence, of some of those in charge; till, at length, the skilful pilotage of Samuel Clegg, who eventually assumed the command, brought her into smooth waters.

It is not surprising that mistakes were made at first, and that immediate success failed to attend the early efforts of the promoters of gas enterprise. The art was a new one; nothing akin to it was there to serve as a model or afford direction and guidance. All the appliances of manufacture, purification, storage, and distribution had not only to be made but invented. The prejudices of the public, too, had to be overcome.

Winsor, with the best intentions, scarcely helped to remove those prejudices. His enthusiastic advocacy, with something of foresight, had in it much of unwisdom. He projected the wildest schemes of gas enterprise ere yet the public—even the immediate public who listened to his harangues and read his pamphlets—had had time or opportunity to grasp the importance of the subject.

Gradually, however, confidence was established. Distrust gave way to admiration; for, under the daily improving management, the new artificial light was shown to be not only cheaper and safer, but vastly superior in lighting power, cleanliness, and handiness, to anything previously in use.

Other companies were soon established in the Metropolis. One by one (like stars coming out at dusk) the larger towns of the kingdom had each its gas company, lighting the public streets and thoroughfares, and supplying its growing number of private consumers.

Thus the new art grew from precarious childhood into youth and sturdy manhood.

It is not too strong an assertion to make, that gas-lighting, during the century of its existence, has proved one of the greatest boons enjoyed by civilized humanity, and no industry that can be named has had a steadier or more abundant success.

This success has been due to two main causes: The inherent utility and value of the invention, and the skill, probity, and business capacity of most of those who, in the earlier years, took a leading part in its furtherance.

The progress which has been made during the century in the machinery of gas manufacture is very striking. This has not been a mere advance in the capacity of the various appliances due to the growing demand for gas-lighting on the part of consumers, but is a positive revolution in constructive detail.

In the first days of the invention the retorts used were of iron, and were placed in the vertical position in the furnace. This was the mode of erection which would be naturally adopted at first, inasmuch as it would lend itself to convenience in depositing the charge.

But it was very soon found that the difficulty of withdrawing the residual coke was such that an alteration in the position was an absolute necessity. Accordingly, no long time elapsed before the retorts began to be laid, first at an inclination, and then horizontally; and instead of only one retort, two, three, and eventually five, were set together and heated, at first by two furnaces, but later by one furnace only.

This was a manifest improvement, and it held its ground for many years. At the present time, in all considerable gas-works, settings of six, seven, eight, nine, and even ten and eleven retorts are in vogue.

Gradually it was found that a high temperature was necessary for economical distillation, inasmuch as with the lower ranges of temperature it was seen that, instead of the evolution of gas, the products were largely in the liquid form.

The retorts themselves were originally of cast-iron, and continued so to be till well into the middle of the century. As the advantages of the higher temperatures of distillation began to be recognized, these were gradually replaced, though not without a struggle, by retorts made of moulded fire-clay, or built up of segmental bricks and tiles.

Instead of direct firing, the regenerative method of heating the retorts, whereby the solid coke is converted into gaseous fuel (CO), is rapidly becoming generally applied, and with marked advantage from every point of view.

The ironwork mountings of the retort bench have undergone considerable modification and improvement during the century. Self-sealing lids, the invention of Mr. Robert Morton, for the retort mouthpieces, have been introduced. The ascension, bridge, and dip pipes have been modified and enlarged; and the hydraulic main is now made of mild steel, and of an improved pattern. Subsidiary or foul mains have been added, by which the gas and denser liquid products are conveyed separately away.

The problem of the application of machinery in gas manufacture, and the consequent saving of manual labour, is advancing towards perfection. This was the dream of the early gas engineers, some of whom attempted it without success. With an ingenuity and persistency deserving of all praise, Mr. John West has devised machinery for stoking, and has, year by year, improved both his hand and power charging and drawing machines. Mr. William Foulis has also been a pioneer in the same direction, and his machinery for that purpose finds wide acceptance.

Inclined or sloping retorts, set at an angle of 30 to 33 degrees, are the latest development in the carbonizing department of a gas-works. Settings of this kind, employed by M. Coze, of Rheims, attracted much attention about eight years ago, and have been adopted at a number of gas-works in this country and abroad. The method and appliances for charging the sloping retorts were imperfect and unsatisfactory at the beginning. Charging appliances of a new type have been introduced, making the system thoroughly practicable. Without doubt, a great future awaits the system, as it simplifies the operations and mitigates the labour in the retort house, besides increasing the productive capacity of the available floor area. The idea of employing retorts set in the inclined position was not new, but an impetus was given to the system by its adoption at Rheims.

Whether it will ever be possible to introduce a method of continuous carbonization, the fresh coal being supplied to the retort and the coke discharged automatically, and without cessation in the working, it is difficult to say. Clegg tried it and failed. Other attempts to that end have been made, but hitherto without marked success, unless the

"Yeadon" system may be considered as a step towards a solution of the problem. This has some good points in its favour, but it has yet to be perfected. It certainly is an ingenious attempt to compass that which earlier inventors failed to accomplish.

Machinery and appliances for the conveyance of coal and coke, and the lime and oxide used in purification, from one point to another, are being widely and successfully applied, and are fast becoming an important labour-saving agency.

The process of washing the gas has been advocated and condemned by various authorities at different periods. Washing was common enough in the early days, but by reason of a supposed deteriorating effect on the illuminating power, it was discredited for a time, and scrubbing by an intercepting material presenting a large area of wetted surface to the gas was preferred.

The view has eventually prevailed that washing as well as scrubbing is indispensable, and the result is that various apparatus to accomplish this object have been introduced with excellent effect.

It is now universally admitted that washing and scrubbing, both with clean water and ammoniacal liquor, are absolutely necessary in order to remove the lighter tars, and arrest the ammonia impurity, as well as to eliminate a proportion of the sulphuretted hydrogen and carbonic acid from the crude gas. It may be safely asserted that the gas of to-day as supplied to consumers is absolutely free from the objectionable ammonia, with the further advantage that this is secured for sale at the gas-works.

The same can be said as regards sulphuretted hydrogen and carbonic acid. In all well-managed gas-works these impurities are unknown in the distributed gas. The use of lime secures their removal with ease and certainty.

Lime was the only medium employed for arresting sulphuretted hydrogen in the earlier days of gas-lighting, till Mr. F. C. Hills introduced the use of hydrated peroxide of iron for that purpose; and although this has no affinity for carbonic acid, the latter impurity is taken out by passing the gas through lime either in the first instance, or in the last stage of purification.

The advantage of using the oxide of iron is its economy, as it can be revivified by exposure to the air after it has become foul, and can be used over and over again, till its bulk has been about doubled by the presence of free sulphur. It also secures another important

desideratum—the reducing of the mountains of foul or spent lime that would otherwise accumulate in the gas yard, and for which there is no great demand on the part of agriculturists. True, a process of spent lime revivification has been invented by Mr. George Hislop; but although this is efficacious in action, it has not been widely adopted.

With the advent of Mr. George Livesey as Engineer-in-Chief of the South Metropolitan Gas Company, a new era in gasholder construction may be said to have begun. It is interesting to note the progress made in his several remarkable structures. The first of Mr. Livesey's notable holders, erected at the Old Kent Road Station, consists of two lifts. It is 180 feet in diameter, and the two lifts rise to a height of 90 feet when fully inflated, the capacity being 2 million cubic feet. His next holder at the same station has a diameter of 214 feet, is in three lifts, and stands when full at a height of 160 feet, having a capacity of 5½ million cubic feet. The third one, erected at East Greenwich, is in four lifts, 250 feet in diameter, and rises to a height of 180 feet, its capacity being 8½ million cubic feet. The latest and largest gasholder in the world is also erected at East Greenwich. This is a veritable monster in size, being 300 feet in diameter, having no fewer than six lifts, and rising when inflated to a height of 180 feet; its capacity being 12 million cubic feet.

But it is not their size only which makes these enormous vessels remarkable; their structural features are equally noteworthy. Instead of the usual guide framing consisting of columns or standards of large bulk and weight, Mr. Livesey in his later structures introduced a guide framing consisting of comparatively light members, the standards being braced together by diagonals, and horizontal struts.

Although the two holders last referred to are of four and six lifts respectively, the guide framing is not carried up to the full height reached by the inflated vessels. In the first, the inner or top lift rises beyond the framing; and in the second, the two innermost lifts ascend above the summit of the framing, their stability under wind pressure being sufficiently assured on cupping by the limited guide framing applied.

Whether the last mentioned vessel at East Greenwich will ever suffer eclipse by a larger one remains to be seen; but certainly it is safe to assert that it never entered into the dreams of the most advanced gas engineers of the first half of the century that holders of

anything like the enormous proportions named would be called into existence.

There is neither the scope nor the necessity in the provinces for holders of the size of the last named, but Mr. Charles Hunt, at the Windsor Street Station of the Birmingham Corporation Gas-Works, has recently erected two with a capacity of 6½ million cubic feet each. These are in three lifts, rising to a total height of 150 feet, the diameter of the outer lift being 286 feet in each instance.

A remarkable innovation in gasholder guiding, by which the upper framing is dispensed with altogether, is due to the inventive genius of Mr. William Gadd, of Manchester. Mr. Gadd solved the problem in a variety of ways. First, by means of torsional and tensional gearing fixed round the tank, and attached to the holder or floating vessel at its base; but more especially by the introduction of spiral guide rails fixed to the sides of the tank or attached to the sides of the holder in a diagonal direction. The simplicity of this latter device is so self-evident that it is matter for surprise it had never been previously applied or thought of. The first holder of this class was erected at Northwich, in Cheshire, by Clayton, Son, & Co., Ltd., of Leeds, having been designed from the inventor's patent specification by the present writer.

As frequently happens in other cases, there were other minds simultaneously engaged in the solution of the problem of guiding holders without upper framing. Mr. E. L. Pease, of Stockton-on-Tees, invented a system of guiding by means of wire rope gearing, which has been largely adopted; and Mr. J. W. Terrace, of Brechin, also devised a means of guiding by shafting, screws, and wheels. Mr. Gadd's, however, was the patent first in the field.

In the distribution department the improvements have been in the direction of efficiency rather than novelty. An exception to this statement must be made in regard to the jointing of main pipes. The open joint, filled either with lead or some kind of cement caulking, was general down to the introduction of the turned and bored joint by Mr. Alfred King, of Liverpool, about the year 1826. This was without question a step in advance, and although there are engineers who still prefer the open joint, the preference arises more from prejudice than experience and knowledge. The turned and bored joint, with a recess in front for filling with cement or lead, is the most perfect joint possible for mains.

There can be no doubt, also, that much of the success of the coal gas industry is due to the adoption of enlarged mains and service pipes, as compared with the restricted sizes in use from twenty-five to thirty years ago; admitting, as they do, of a reduction in the pressure, with a consequent reduction of loss by leakage, and an increased illuminating value.

In street lighting a marked advance has been witnessed. Perhaps this is due to some extent to the threatened competition of the electric light. Years ago Mr. William Sugg introduced his large argands for street lighting. These undoubtedly gave a magnificent light, but the difficulties attending the regulation of the flame at varying pressures proved an impassable obstacle to their success, and they were finally abandoned.

These were succeeded by the triform arrangement of large flat-flames, introduced almost simultaneously by Mr. Sugg and Mr. George Bray. For the illumination of streets, squares, and other wide open spaces they are admirably adapted.

The Welsbach system of incandescent gas lamps, introduced in the year 1887, has created a veritable revolution in domestic lighting, and it bids fair to revolutionize the lighting of streets also. The success of the invention has been as great as it is deserved; not only is the gas economized by its use, but the illuminating value of the light is increased to the extent of 300 to 400 per cent.

The use of gas for cooking and heating, for the production of motive power, and for workshop purposes, has made vast strides of recent years. Fires, stoves, and ranges of all sizes and of excellent design, are produced by a number of first-class makers. The Otto gas engine, as made by Crossley Brothers, has settled beyond question the economy and value of gas for motive power. Other makers of similar engines of great excellence are numerous. In the application of gas to industrial uses generally, the ingenuity of Mr. Thomas Fletcher has found an outlet. In all these directions the field may be pronounced limitless.

The invention and introduction of the prepayment meter has encouraged the use of gas by the poorer class of consumers, and here also it is difficult to conceive of a limit to gas enterprise.

In no department of the gas industry has there been so remarkable a development as in that of dealing with the residual products. There is absolutely no waste in a well-managed gas-works. Everything is utilized, even to the dross yielded by the furnaces. This much can

hardly be asserted of any other industry in existence, and this fact should be borne in mind by those who are sometimes inclined to decry the administrators of gas undertakings.

The tangible result of it all is, that gas property has attained to a reputation for value and stability, scarcely exceeded by any other means of investment outside the Funds, and, competition notwithstanding, there is ground for confidence that it will continue to maintain its deserved popularity.

COAL.

The geological position of coal in the earth's crust is shown in the annexed tabular view of the trias, permian, and carboniferous series in England and Wales, by Professor Hull :—

New red sandstone or trias . .	Keuper	Red marl.
		Lower Keuper sandstone.
	Bunter	Upper mottled sandstone.
		Conglomerate beds.
		Lower mottled sandstone.
Permian rocks		Upper red sandstone of St. Bees, &c.
		Upper and lower magnesian limestones and marls of the Northern counties.
		Lower red sandstone of Lancashire, Cumberland, and Yorkshire, &c. (on the same horizon with)
		Red sandstones, marls conglomerates, and breccia, of the central counties and Salop.
Carboniferous rocks.	Upper carboniferous	Upper coal-measures, with limestone, and thin coal seams.
		Middle coal-measures, with thick coal seams.
	Lower carboniferous	Lower coal-measures, or Gannister series, with thin coal seams and lower carboniferous fossils.
		Millstone grit, with thin coal seams.
		Upper limestone shale, or Yoredale rocks.
		Carboniferous limestone with shales, sandstones, and coal in the Northern counties and Scotland.
		Lower limestone shale.

Old red sandstone and Devonian rocks.

The area of the coal measures in the United Kingdom is as follows:—

	Area of Coal Measures.		Entire Area of Country.		Proportion of Coal to the whole.
	Square Miles.	Acres.	Acres.	Square Miles.	
In England	6,089	3,864,960	31,770,615	49,643	1-8th
In Scotland & Islands, exclusive of Lakes .	1,720	1,100,000	18,944,000	29,600	1-18th
In North Wales . . .	210	134,400	4,752,000	7,425	1-6th
In South Wales . . .	950	608,000			
In Ireland	2,940	1,881,600	20,399,608	31,874	1-11th
In Islands	..	..	1,119,159	1,748	—
Total . . .	11,859	7,588,960	76,985,382	120,290	—

Exclusive of wood-coal and lignite formations, and some small undefined areas.

The chief kinds of coal in the United Kingdom are—

Cannel or Parrot Coal.—This is the richest gas-producing coal, and is easily distinguished by its hard, smooth texture. The best varieties are found in different parts of Scotland, in Wales, and at Wigan and Newcastle or their neighbourhood. The latter two yield coke of fair quality; that from the other is less valuable, and much of it is useless as fuel.

Bituminous Coal.—For gas producing purposes the coal most suitable is the bituminous class, which includes caking, splint, cherry, and other coals containing bitumen. It is found widely distributed throughout the kingdom, in Yorkshire, Lancashire, Cumberland, Northumberland, Durham, Derbyshire, Staffordshire, Gloucestershire, Somersetshire, portions of Scotland and Wales. It yields coke generally of excellent quality.

Anthracite or Glance Coal.—This is chiefly Welsh, containing a large proportion of fixed carbon (over 90 per cent.) and but little volatile matter. It glows rather than flames in burning, and is almost smokeless. It is excellent for steam raising purposes and domestic

use where a good draught is available, but is quite useless for the production of illuminating gas.

Lignite or Brown Coal.—This is found at Bovey Tracey, in Devonshire, in a small field near Lancaster, and near to Lough Neagh, in Ireland. It yields but little gas, and that of a low illuminating power and very unpleasant odour. In distillation it gives off a large quantity of water charged with acetic acid, and the residual coke is valueless as fuel. It is, therefore, of no great interest to the gas maker.

The tables annexed show the specific gravity of coals, the chief substances of which they are composed, and their yield of coke per cent. :—

NEWCASTLE COALS.

Name of Coal.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Willington	..	86·81	4·96	1·05	0·88	5·22	1·08	72·19
Tanfield	1·26	85·58	5·31	1·26	1·32	4·89	2·14	65·13
Bowden Close	..	84·92	4·53	0·96	0·65	6·66	2·28	69·69
Haswell Wallsend	1·28	83·47	6·68	1·42	0·06	8·17	0·20	62·70
Newcastle Hartley	1·29	81·81	5·50	1·28	1·69	2·58	7·14	64·61
Hedley's Hartley	1·31	80·26	5·28	1·16	1·78	2·40	9·12	72·31
Bates's West Hartley	1·25	80·61	5·26	1·52	1·85	6·51	4·25	..
West Hartley Main	1·26	81·85	5·29	1·69	1·13	7·58	2·51	59·20
Original Hartley	1·25	81·18	5·56	0·72	1·44	8·03	3·07	58·22
Average of eighteen samples from different mines	1·25	82·12	5·31	1·35	1·24	5·69	3·77	60·67

LANCASHIRE COALS.

Ince Hall Company's Arley	1·27	82·61	5·86	1·76	0·80	7·44	1·53	64·00
Haydock, Rushey Park	1·32	77·65	5·53	0·50	1·73	10·91	3·68	59·40
Blackbrook, Little Delf	1·26	82·70	5·55	1·48	1·07	4·89	4·31	58·48
Wigan four feet	1·20	78·86	5·29	0·86	1·19	9·57	4·23	60·00
,, Cannel	1·23	79·23	6·08	1·18	1·43	7·24	4·84	60·33
Caldwell and Thompson's Higher Delf	1·27	75·40	4·83	1·41	2·43	19·98	5·95	54·20
Average of twenty-eight samples from different mines	1·27	77·90	5·32	1·30	1·44	9·53	4·88	60·22

DERBYSHIRE COALS (Fiddes).

Name of Coal.	Specific Gravity.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Coke.
Earl Fitzwilliam's Elsecar.	1·296	81·93	4·85	1·27	0·91	8·58	2·46	61·60
Holyland and Co.'s Elsecar	1·317	80·05	4·93	1·24	1·06	8·99	3·73	62·50
Butterley Co.'s Langley . .	1·264	77·97	5·58	0·80	1·14	9·86	4·65	54·90
Staveley	1·270	79·85	4·84	1·28	0·72	10·96	2·40	57·86
Average of seven samples from different mines . .	1·292	79·68	4·94	1·41	1·01	10·28	2·65	59·32

GLOUCESTERSHIRE COALS.

Coleford High Delf (Forest of Dean) .	1·219	78·810	5·308	1·750	2·062	9·055	3·020	63·97
" "	1·313	76·502	5·380	1·090	1·669	8·659	6·700	62·60
" "	1·331	74·410	4·470	0·700	2·370	8·840	9·210	59·76
" "	1·354	74·464	5·292	0·511	2·667	6·831	10·235	60·36
Trenchard	1·354	80·709	5·425	0·735	1·271	7·060	4·800	63·38
New Bowson, Cinderford .	1·332	76·860	5·430	1·680	1·940	9·330	4·760	58·24
" " .	1·307	79·310	5·250	1·260	0·850	9·100	4·230	59·22
Parkfield	1·374	82·069	5·613	0·940	1·457	6·391	3·530	60·97
Hanham	1·277	75·340	4·630	0·630	2·440	5·480	11·480	58·86
Warmley	1·304	82·410	4·870	0·770	0·870	5·230	5·850	71·15

SCOTCH COALS.

Boghead	1·218	63·930	8·858	0·962	0·320	4·702	21·222	31·70
Wallsend Elgin	1·200	76·090	5·220	1·410	1·530	5·050	10·700	58·45
Grangemouth	1·290	79·850	5·280	1·350	1·420	8·580	3·520	56·60
Eglinton	1·250	80·080	6·500	1·550	1·380	8·050	2·440	54·94

WELSH COALS (Fiddes).

Aberaman, Merthyr . . .	1·300	90·940	4·280	1·210	1·180	0·940	1·450	85·00
Aberdare Co., Merthyr . .	1·310	88·280	4·240	1·660	0·910	1·650	3·260	85·83
Anthracite (Jones & Co.) .	1·375	91·440	3·460	0·210	0·790	2·580	1·520	92·90
Coleshill	1·290	73·840	5·140	1·470	2·340	8·290	8·920	56·00
Llantwit	1·273	77·410	5·553	0·560	2·365	12·062	2·050	64·70
"	1·252	77·810	5·642	0·420	2·037	10·366	4·225	58·82
Nantgarw Llantwit . . .	1·326	79·130	5·610	0·700	3·450	7·330	3·780	61·67
Rhos Llantwit	1·282	76·995	5·455	0·700	1·643	12·875	2·332	63·30
" "	1·302	75·452	5·497	0·840	2·312	13·023	2·876	68·08
" "	1·302	73·410	5·507	0·350	2·414	14·276	4·043	65·32
Holly Bush	1·269	80·134	5·045	0·518	2·279	8·522	3·502	74·42
Tyr Filkens	1·368	82·117	5·054	0·595	2·537	5·794	3·903	64·86
Llanhilleth	1·274	87·640	6·085	1·120	1·636	2·209	1·310	70·39
Aber Rhondda	1·320	80·675	5·082	0·910	3·675	2·768	6·895	70·81
Pontypridd	1·311	79·820	5·470	0·700	3·950	3·750	6·310	65·80
Wallsend	1·317	78·270	5·380	0·770	1·860	8·900	4·820	66·00
Energlyn	1·312	83·120	5·840	0·980	1·870	5·890	2·300	71·30
Rock Vawr	1·290	77·980	4·890	0·570	0·960	8·550	7·550	62·50

The specific gravity both of cannel and bituminous coals averages about 1·270, distilled water at 62° Fahr. being 1·000.

The proportion of ash in the better class of bituminous coals averages 2·5, and in the residual coke 3·75 per cent. In cannel, the proportion of ash is much greater.

The colour of the ash varies, according to the nature of its constituents, from white, through all the gradations of grey, cream colour, fawn colour, yellow, pink, red, to deep red and brown.

The following is an analysis of the ash of a good Newcastle coal:—

	Per cent.
Silica	59·56
Alumina	12·19
Peroxide of iron	15·96
Lime	9·99
Magnesia	1·13
Potash	1·17
	100·00

The proportion of sulphur in fourteen samples of cannel averaged 1·21, and in forty-two samples of bituminous coal 1·812 per cent.

In the same samples the volatile matter and coke were as follows:—

	Volatile Matter. Per cent.	Residual Coke. Per cent.
Cannel	44·71	55·29
Bituminous coal	34·72	65·28

Every-day experience shows that variations occur in the quality of the coal obtained from the same seam and in the same locality. The identical seam of coal also varies in quality in different districts.

Coal got from those parts of the bed where the seam is thickest is more likely to possess uniformity of structure than that got near to the circumference of the basin.

Mr. E. W. Binney's observations led him to the conclusion that seams of coal are materially affected by the nature of the super-imposed strata. If this is of an open character, such as sandstone, the gaseous matter can readily escape. On the other hand, if the roof is of almost air-tight black shale or blue blind, the gas is retained.

Further, it is not unreasonable to infer that the vegetable matter of

which coal is composed would be deposited irregularly. For example, during the ages of primeval vegetable growth, a larger proportion of leaves would be deposited in some places than in others where the deposits of bark and cellular tissue would be in excess. These conditions would naturally tend to produce variations in quality.

In seams of cannel there is more uniformity of quality than in those of ordinary coal, due to the circumstance, as is supposed, of their having been formed from vegetable matter long macerated in water, thus insuring a more intimate admixture of the vegetable substances.

It is well known that variations in the gas-producing qualities of coal are caused by the material having been stacked for a length of time on the pit bank.

It is important that the coal which is to undergo distillation should be clean and dry.

When coal in a wet or moist condition is placed in the retorts, the results are unsatisfactory in several respects.

In the first place, the temperature of the retorts is reduced, and, as a consequence, extra fuel is consumed in restoring the temperature, and in drying the coal by evaporating the moisture and driving it off as steam before the coal is in a fit condition to undergo destructive distillation.

Again, a portion of the moisture or steam is decomposed in contact with the sulphide of iron produced by decomposition from the bisulphide of iron or iron pyrites contained in the coal. The oxygen combines with the iron, forming the oxide of that metal, and the hydrogen with the sulphur, producing sulphuretted hydrogen. Bisulphide of carbon and other sulphur compounds are also formed in considerable volume.

In this way the whole of the sulphur present in the coal is caused to pass off into the gas, and has to be subsequently removed in the process of purification, thus increasing the cost of manufacture.

On the other hand, when the coal is distilled in a dry condition, rather more than one-half of the sulphur present is left behind in the residuary coke.

Sulphur exists in cannel in the free state, and in bituminous coals chiefly in combination with iron, as pyrites or bisulphide of iron, FeS_2, and this in the retort is converted into sulphide or protosulphuret of iron, FeS.

SOME RECENT ANALYSES OF COALS AND CANNELS.

By T. and W. Newbigging.

GAS COALS.

Name of Coal.	Situation.	Specific Gravity of Coal.	Yield of Purified Gas per Ton in Cubic Feet.	Illum. Power of the Gas in Standard Candles	Value of 1 Cubic Foot of Gas in Grains of Sperm	Value of Gas per Ton of Coal in lbs. of Sperm.	Sulphur in Coal per Cent.	Coke in lbs. per Ton.	Ash in Coke per Cent.
Haigh's Black Bed	Bruntcliffe, near Leeds	1·314	11,850	18·36	440·64	714·46	1·46	1,409	8·48
Ditto Beeston Nuts	Bruntcliffe, near Leeds	1·246	11,500	18·74	449·76	738·89	·86	1,390	8·30
Ditto do. Top Seam	Bruntcliffe, near Leeds	1·267	11,800	21·34	512·16	863·35	·89	1,375	8·05
Hoyland Silkstone	Barnsley	1·287	11,950	17·72	425·28	726·01	1·06	1,500	6
Ditto New Silkstone	Ditto	1·270	11,850	18·36	440·64	745·94	1·10	1,453	4·55
Ditto Silkstone Cobbles	Ditto	1·256	11,550	18·09	434·16	716·36	·52	1,484	4·50
Middleton Main Screened	Soothill Wood, Batley	1·268	11,575	18·98	455·52	753·23	1·29	1,406	2·50
Beeston Coal	Dewsbury	1·263	10,300	21·28	510·72	751·48	·45	1,390	2·75
Middleton Coal	Ditto	1·271	10,100	21·37	512·88	740·01	·35	1,406	1·67
Bersham Main	North Wales	1·268	12,100	16·94	406·56	702·76	·23	1,321	5·65
Ditto Quaker	Ditto	1·349	12,000	15·52	372·48	638·54	·24	1,368	12·37
⅔ Bersham Main, ⅓ Bersham Cannel } Mixed	Ditto	..	11,150	18·81	451·45	719·10	·22	1,320	6·60
Orrel Four Feet	Wigan	1·265	12,050	21·58	517·92	891·56	·37	1,398	8·41
Five Foot Top	Bredbury	1·351	10,200	17·86	428·64	624·59	4·48	1,343	6·65
Ditto Bottom	Ditto	1·291	10,775	17·99	431·76	664·60	·58	1,343	6·10
Ditto Mixed	Ditto	..	10,400	17·96	431·04	640·40	1·13	1,343	6·43
Four Foot	Ditto	1·293	10,400	17·61	422·64	627·92	·85	1,398	6·67
Rodger Mine	Ditto	1·286	10,650	19·29	462·96	704·36	1·02	1,335	10·10
Ramsden's	Tyldesley	1·287	10,975	18·36	440·64	690·86	·64	1,375	12
Ditto	Ditto	1·264	10,337	17·64	423·36	625·18	1·35	1,406	8
Brinsop Hall, Arley	Wigan	..	9,900	17·75	426·00	602·48	..	1,480	..
Muke (selected best)	Japan	1·403	10,200	17·81	427·44	622·84	2·71	1,415	23
Ditto (seconds)	Ditto	2·243	6,600	16·48	395·52	372·92	3·09	1,752	62·32

CANNELS.

Name of Cannel.	Situation.	Specific Gravity of Cannel.	Yield of Purified Gas per Ton in Cubic Feet.	Illum. Power of the Gas in Standard Candles.	Value of 1 Cubic Foot of Gas in Grains of Sperm.	Value of Gas per Ton of Cannel in lbs. of Sperm.	Sulphur in Coal per Cent.	Coke in lbs. per Ton.	Ash in Coke per Cent.
Haigh's Beeston Top Seam	Bruntcliffe, near Leeds	1·331	11,400	24·82	595·68	970·10	·97	1,406	13·25
Low Laithes	Ossett	1·270	12,650	24·76	594·24	1078·88	1·19	1,250	6·75
Soothill Wood Company	Batley	1·281	12,325	26·03	624·72	1099·95	1·51	1,289	9·95
Ditto Johnnies	Ditto	1·535	11,000	27·76	662·46	1046·95	2·21	1,297	48·94
Dressed Johnnies	Ditto	1·268	12,050	26·75	642·00	1105·16	1·84	1,265	32·07
Chickenley Heath	Dewsbury	1·288	12,400	26·47	635·28	1125·35	1·38	1,281	15·70
Crawshaw and Warburton	Ditto	1·264	10,000	27·08	649·92	928·45	1·15	1,297	10·4
Ditto do.	Ditto	1·290	10,502	24·51	588·24	882·52	·73	1,297	31
Padeswood Bottom	Mold, Wales	1·449	11,700	21·84	524·16	876·09	·41	1,065	52·80
Ditto Smooth	Ditto	1·277	11,300	22·38	537·12	867·06	·74	1,208	6·50
Ditto Curley	Ditto	1·158	12,630	40·58	978·92	1757·23	·43	747	26·00
Pontybodkin	Ditto	1·121	12,300	37·79	906·96	1598·65	·736	765	23
Silverhill	Stanton	1·299	9,900	19·02	456·48	645·60	..	1,219	8·30
Bersham	North Wales	1·274	13,000	22·83	547·92	1017·57	·20	1,248	5·90
Bradford Estate	Great Lever	1·264	11,150	23·56	565·44	900·66	·58	1,359	4
Blaydon Main	Durham	1·329	10,950	27·48	659·52	1081·86	·10	1,453	11·70
Westleigh	Lancashire	1·193	14,795	27·50	660·00	1394·96	·69	1,008	6·50
Ramsden's	Tyldesley	1·418	10,150	23·46	568·04	816·40	·88	1,250	25·50
Cloverport or Breckenridge } Top	Kentucky, U.S.A.	..	12,800	25·00	600·00	1097·14	..	1,070	..
Cloverport or Breckenridge } Middle	Ditto	..	14,350	39·40	945·60	1938·48	..	672	..
Ditto do. Bottom	Ditto	..	12,333	28·33	679·92	1197·92	..	969	..
Sydney Shale	N.S. Wales	1·163	14,930	36·68	880·32	1878·00	..	624	78·00
Turner's New Abram	Wigan	1·119	14,710	39·38	945·12	1986·10	·535	917	6·45

The Storage of Coal.—In gas making it is economical to use the coal as fresh as possible from the pit; but to be prepared for emergencies, the covered storage room for coal and cannel should be of capacity sufficient to contain from six to eight weeks' stock of the material, reckoned on the basis of the heaviest day's consumption in winter.

An exception to this rule may be made in the case of gas-works situated in the immediate vicinity of the coal fields from which the supply is derived. Under such circumstances, provision for two or three weeks' stock is ample.

In storing coal 48 cubic feet of space per ton is required.

All kinds of coal suffer deterioration by exposure to the weather, both as regards their heating, coking, and gas-yielding qualities.

When coal is so exposed, being stored in the open air without any protecting covering, it is not only liable to be wetted by rain on its outer surface, but it also absorbs and retains moisture within its structural interstices.

The effect of this excess of moisture is to cause disintegration, reducing the size of the lumps, and converting them to a considerable extent into dust and coom.

The exposure of the coal in the winter season in this climate is, of course, the most objectionable as regards disintegration. In hot climates the intense heat of the sun produces the disintegration.

The ill-effects of this absorption of moisture do not end there. Oxidation of the particles of the coal also ensues; and as this is only another name for eremacausis or slow-burning, the material is not only reduced in weight, but its gas-producing power, both as to quantity and quality, and its coking qualities, are greatly impaired.

An absolute loss of weight, due to the evaporation or slow combustion of the more volatile constituents, is also experienced. This is particularly the case with bituminous or caking coal; cannel suffers next in degree; and anthracite the least. Varrentrapp found in one instance that coal which had been exposed for some years to the weather had diminished in weight to the extent of 33·03 per cent.

Wet or damp coal not only yields less gas, but gas of an inferior quality. The sulphur impurities given off from it are more, thus augmenting the cost of purification; whilst some of the sulphur

compounds—notably bisulphide of carbon—are not removable except by a greatly increased area of purification beyond what is to be found in most gas-works.

Spontaneous Ignition of Coal.—Coal containing a large proportion of iron pyrites (bisulphide of iron), commonly called "brasses," when stored in a compact mass in a wet or humid state, is liable to spontaneous ignition. This is not an unusual occurrence in the experience of the gas manager. The indications that combustion has begun are a sensible rise in the temperature of the coal store, a sickly odour, and a choking or smothering sensation in drawing breath.

There is this liability to spontaneous ignition in almost all bituminous coals of a friable nature. It is due to more than a single cause. It may arise from the condensation of oxygen within the pores of the carbonaceous particles, just as oily cotton waste will fire spontaneously in the same way by the rapid absorption of oxygen. According to Professor Abel and Dr. Percy, water or moisture does not accelerate, but rather retards, spontaneous ignition under these circumstances.

The danger of firing is greatest with those coals which contain a large proportion of iron pyrites in the shape of nodules, or "brasses," as they are called, and which are stored in a deep mass in the wet condition. These "brasses" become oxidized by the atmospheric oxygen dissolved in the water with which the coal is saturated; and the heat thus generated raises the temperature of the coal to ignition point.

Notwithstanding a conflict of opinion on the subject, we believe that the best remedy for this is ventilation.

Various expedients are resorted to for effecting this object, amongst which may be mentioned the insertion in the mass of coal of perforated iron pipes with the ends exposed; coarse wickerwork baskets, without bottoms, are used with good results; and ventilating shafts of brick, or venetianed shafts of wood, both horizontal and vertical, have proved efficient. Unless the ventilation is thorough, however, the admission of air will do more harm than good, as a sluggish current will not reduce the temperature, but rather tend to develop and increase it.

A thermometer let down through the pipes or shafts will indicate any rise of temperature, and iron rods thrust into the mass of coal, when withdrawn and touched by the hand, will answer the like purpose.

When the pyrites are present to a serious extent, the coal should be hand-picked, either at the colliery or when discharging at the gas-works. It is only sheer necessity, however, that will justify the employment of coal of this character for gas-making purposes.

The Gases Occluded in Coal.—Besides the liability to spontaneous combustion or ignition, there is another strong reason why coal should not be stored in the open air, nor, indeed, under cover, for a longer time than is absolutely necessary.

In all bituminous coals a constant chemical change is in progress, by which gas is being liberated. This gas, though frequently several times the volume of the coal, is condensed within the solid substance, being occluded or enclosed therein, until by diffusion it escapes into the air, and to such extent the coal is depreciated for gas making.

In warm weather and in hot climates this deterioration proceeds more rapidly than in low temperatures.

Dr. Lyon Playfair and others in this country, and Dr. E. von Meyer in Germany, have investigated the subject; and the subjoined table by the latter shows the quantity and composition of the gas so occluded, obtained from freshly raised samples of coal submitted to him for analysis.

The plan adopted was to place 100 grammes of the coal in hot de-aërated water, which was then boiled as long as any gas continued to be given off, and the gas collected was analyzed by Bunsen's methods.

Samples of Coal Submitted.			Fathoms from Surface.
No. 1. Low Main Seam,	Bewick Colliery,	Newcastle.	—
2. Maudlin Seam	ditto	ditto	—
3. Main Coal Seam,	Urpeth Colliery,	ditto	—
4. Five-fourth Seam,	ditto	ditto	30
5. Ditto	Wingate Grange Colliery, Durham		74
6. Low Main Seam,	ditto	ditto	108
7. Harvey Seam,	ditto	ditto	148
8. Ditto	Emily Vil, Woodhouse Close Colliery		25

ANALYSIS.

Percentage Composition of the Gas.

Coal as above.	CO_2	CH_4 Marsh Gas.	O	N	Cubic Centimètres of Gas from 100 Grammes of Coal.
No. 1 . . .	5·55	6·52	2·28	85·65	25·2
2 . . .	8·54	26·54	2·95	61·97	30·7
3 . . .	20·86	..	4·33	74·31	27·4
4 . . .	16·51	Trace.	5·65	77·84	24·4
5 . . .	0·34	85·80	Trace.	13·86	91·2
6 . . .	1·15	84·04	0·19	14·62	238·0
7 . . .	0·23	89·61	0·55	9·61	211·2
8 . . .	5·31	50·01	0·63	44·05	84·0

1 cubic centimètre = ·061028 cubic inch.

1 gramme = 0·0022 lb. avoirdupois, 100 = 0·22 lb.

The Testing of Coal for its Producing Qualities.—It is almost impossible to judge from the appearance of a coal whether its gas and coke-yielding qualities are good, bad, or indifferent. So far as outward indications go, nothing is so deceptive to the inexperienced in such matters; and even to those who have had large practice in coal-testing, it is very difficult to forecast with any certainty the result of a trial of any particular sample.

The most favourable signs are when the coal exhibits traces of carbonate of lime and charcoal deposits on the surfaces exposed by fracture, and the appearance of a brownish coloured streak on being scored with a hard, blunt point. This latter is an invariable sign of richness.

Some of the poorest coals and cannels have a fatty, unctuous appearance, suggestive of richness in gaseous properties; again, the most valuable cannels and shales, yielding gas in extraordinary abundance, have a dull earthy cast, which might readily be taken as indicating poverty of composition and yield. The rich Boghead (Scotland), Sydney (New South Wales), Cloverport (Kentucky) cannels or shales, and the New Abram cannel, Wigan, are striking examples of this latter kind. On the other hand, this does not hold good of the Brazilian shales or "Turba." These have a dull, clayey appearance, and are very indifferent both in the yield and in the illuminating

power of their gas. The importance of being able to test samples of coal or cannel, before entering into a contract for the material in bulk, is therefore obvious.

A test may be made either on a working scale, or in the experimental apparatus in the gas manager's laboratory. In the former case several tons of the material have to be used, and the trial of a single sample is a formidable and tedious process, extending over many days, until the old gas in the apparatus and holder has been replaced by the new. It is obviously impossible to test a variety of samples in this manner within a reasonable period. Besides, such a method of testing is not always satisfactory. The manager has to take a good deal for granted; he is largely dependent on subordinates for the attention and care that ought to be exercised, because his constant personal supervision throughout the time occupied by the test is out of the question.

The experimental test is to be preferred for many reasons. The small apparatus is more under the command of the operator. Full justice is done to the material. The best results it is possible to obtain are secured. Time is economized in making the tests, because a number of samples can be tried in the course of, say, ten to fourteen days.

It may be urged against the experimental, or laboratory test, that, in practical working, equal results are unattainable. If this be the fact, it only proves that either the practical working is at fault to the extent of the difference in result, or that the bulk of the material is not equal to the sample tested.

Assuming, however, that the sample is a fair average of the whole, whatever the deficiencies of practical working may be, the coal at least should not be depreciated below its intrinsic value through defective heats and other faulty methods of carbonization; and although the actual every-day working of the material may afterwards fall short of the results obtained in the trial apparatus, these latter are a standard at which to aim. As a general rule, the difference between the results of actual use and the experimental results, with efficient plant and careful supervision, will not exceed seven to ten per cent. in favour of the experimental test.

To argue that the quality of a coal should be judged and determined solely by the results yielded in actual working, is just about as reasonable as to say that the illuminating power of gas should be decided

by the methods of consumption through possibly defective fittings, and some of the burners largely in use by consumers. Whether coal or gas, the means best calculated to develop its intrinsic qualities should be adopted.

Care should be taken to obtain a fair sample of the coal to be operated upon. For that purpose a full section of the seam should be obtained. It should then be broken up into small pieces and thoroughly intermixed, and from this, three several charges should be taken without selection.

The charge employed in the laboratory trial is the 1000th part of a ton—viz., 2·24, say 2¼, lbs.

The following are the details of the testing apparatus (Fig. 1).

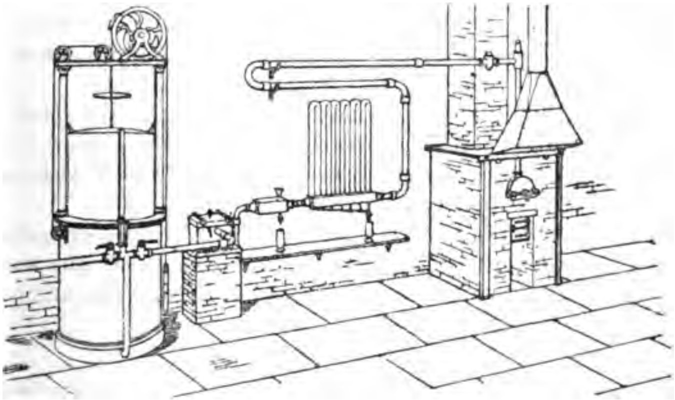


Fig. 1.

Retort.—Cast iron; D-shaped; 5 in. wide, 4½ in. high, inside; 2 ft. 8 in. long, outside; ½ in. metal.

Ascension Pipe.—2 in. wrought tube.

Connections.—1½ in. wrought tube.

Condenser.—12 vertical 1½ in. wrought tubes, 3 ft. 6 in. long each.

Washer.—1 ft. long, 6 in. wide, 6 in. deep.

Purifier.—1 ft. 2 in. square, 12 in. deep, with 2 trays of lime.

Gasholder.—Capacity, 12 cubic feet, with graduated scale attached.

The retort should be got up to, and maintained throughout the charge at, a bright red heat. If from any cause the temperature is

A table, by Dr. Henry, exhibits the qualities of gas at different periods of distillation :—

From Half a Ton of Wigan Cannel.

Time from Beginning of Distillation.	100 Measures of Impure Gas contain		100 Measures of Purified Gas consist of			100 Measures of Purified Gas	
	Sulphuretted Hydrogen.	Other Compounds of Nitrogen and Hydrogen.	Olefiant Gas.	Other Inferior Gases.	Nitrogen.	Consume Oxygen.	Give Carbonic Acid.
½ an hour.	½	5½	16	64	20	180	94
1 hour.	3	3½	18	77½	4½	210	112
3 hours.	2½	2½	15	80	5	200	108
5 ,,	2½	2½	13	72	15	176	94
7 ,,	2	2½	9	76	15	170	83
9 ,,	½	2½	8	77	15	150	73
10 ,,	..	2	6	74	20	120	54
12 ,,	..	½	4	76	20	82	36
From Half a Ton of Common Wigan Gas Coal.							
1 hour.	3	3	10	90	..	164	91
3 hours.	2	2	9	91	..	168	93
5 ,,	3	2	6	94	..	132	70
7 ,,	1	3	5	80	15	120	64
9 ,,	1	2½	2	89	9	112	60
11 ,,	1	1	..	85	15	90	48

The rate of production of gas from 2 cwt. of Wigan coal in an experimental retort was found to be as follows :—

	Cubic Feet.
½ hour	275
1 ,,	245
1½ hours	200
2 ,,	140
2½ ,,	80
3 ,,	40
3½ ,,	20
4 ,,	15
Total	1015

The annexed table, by Miller, exhibits the quantity and specific gravity of the gas obtained from two bushels of coal during each of five hours' heating in an ordinary retort ; and shows the importance of restricting the time during which the coal is subjected to

the action of heat in the manufacture of gas. The rich hydrocarbons diminished, and carbonic oxide and hydrogen increased in quantity as the experiment progressed.

	Cubic Feet.	Specific Gravity.
In the first hour	345	·677
In the second hour	203	·419
In the third hour	118	·400
In the fourth hour	54	·322
In the fifth hour	20	—

With cannel the carbonization takes place in considerably less time than with ordinary coal.

For roughly estimating the weight of coal or cannel required to produce a given quantity of gas:

Rule.—Strike off the last four figures from the quantity of gas produced, and the figures remaining will represent the coal or cannel in tons.

Thus: 20 | 0,000 cubic feet of gas = 20 tons coal.

This will be evident when it is remembered that a ton of coal or cannel produces about 10,000 cubic feet of gas. Should the production rise to 11,000, or fall to 9000 per ton, one-tenth must be deducted from, or added to, the coal, as the case may be.

The average weight of coal per cubic yard is :—

	lbs.
Anthracite, per cubic yard, solid	2160
Bituminous " " " "	2025
Cannel " " " "	2160
Coal, stored in the usual way, per cubic yard	1400
Coke, per cubic yard	670
Breeze " " "	950

The average percentage yield, by weight, of good bituminous coal, is as follows :—

	Per cent.
Gas	18
Coke and breeze	68
Tar	5
Ammoniacal liquor	9
	100

In order to find the value of gas in grains of sperm per cubic foot from the given illuminating power :—

Rule.—Multiply 120 (the grains allowed per hour for the consumption of the standard sperm candle) by the illuminating power,

and divide by 5 (consumption of gas in cubic feet per hour by the standard burner). The answer will be the value of the gas in grains of sperm per cubic foot.

EXAMPLE.—What is the value of gas in grains of sperm per cubic foot, the illuminating power of which is 19·46 candles?

$$\frac{19{\cdot}46 \times 120}{5} = 467 \text{ grains of sperm, value.}$$

To find the value of any coal per ton in pounds of sperm, the yield of gas and illuminating power being known:—

RULE 1.—Multiply the cubic feet produced per ton by the value of the gas in grains of sperm per cubic foot (ascertained by the previous rule), and divide by 7000 (the number of grains in 1 lb. avoirdupois). The answer will be the value of the coal in lbs. of sperm per ton.

EXAMPLE.—What is the value of a certain coal in lbs. of sperm per ton, whose yield of gas is 10,540 cubic feet, and illuminating power 19·68 standard sperm candles?

$$\frac{19{\cdot}68 \times 120}{5} = 471{\cdot}12, \text{ value of the gas in grains of sperm per cubic ft.}$$

Then $\frac{10{,}540 \times 471{\cdot}12}{7000} = 709{\cdot}87$ lbs. of sperm per ton, value. Or by

RULE 2.—Divide the yield per ton by 5 (cubic feet of gas consumed per hour by standard burner); multiply by the ascertained illuminating power and by 120 (consumption of standard sperm candle per hour in grains); lastly, divide by 7000 (number of grains in 1 lb. avoirdupois). The answer will be the value of the coal in lbs. of sperm per ton.

EXAMPLE.—What is the value of a certain coal in lbs. of sperm per ton, whose yield of gas is 10,540 cubic feet, and illuminating power 19·68 standard sperm candles? Then

$$\frac{10{,}540}{5} = \frac{2108 \times 19{\cdot}68 \times 120}{7000} = 709{\cdot}87 \text{ lbs. of sperm per ton, value.}$$

To ascertain the relative value of different coals and cannels, attach

approximate or actual market prices to the sperm pounds as ascertained above, and to the several residual products, cast up the various items, and compare them by the ordinary rule of proportion.

EXAMPLE.—The two coals to be compared are—

No. 1, yielding—

		£	s.	d.
10,600 c. ft. of gas per ton, 17½ candles value = 636 lbs. sperm	at 1s.	31	16	0
13½ cwt. Coke	at 5d.	0	5	7½
10 gals. Tar.	at 1¼d.	0	1	0½
22 gals. Ammoniacal Liquor	at 1d.	0	1	10
		£32	4	6

No. 2, yielding—

		£	s.	d.
9,700 c. ft. of gas per ton, 16¾ candles value = 557 lbs. sperm	at 1s.	27	17	0
14 cwt. Coke	at 5d.	0	5	10
9 gals. Tar	at 1¼d.	0	0	11¼
20 gals. Ammoniacal Liquor	at 1d.	0	1	8
		£28	5	5¼

Assuming that No. 1 is 12s. 6d. per ton, the relative value of No. 2 will be found as follows :—

As £32 4s. 6d. : £28 5s. 5¼d. . 12s. 6d. : 10s. 11½d. value per ton of No. 2.

Farmer's rule to find the relation between quantity of gas per ton and illuminating power, may be quoted here, but it must not be assumed as absolutely correct. It is only approximately so, and that only within a limited range. If a given coal yields a known volume of gas of a known illuminating value, to ascertain how much gas it will yield of another value :—

RULE.—Multiply yield of gas by the illuminating power, divide by the *required* power, and the quotient is the quantity.

EXAMPLE.—A coal yields 9600 cubic feet per ton of 16-candle gas; how much will it yield of 14 and 17 candle gas respectively?

$$9600 \times 16 = 153{,}600. \quad \text{Then}$$

$$\frac{153{,}600}{14} = 10{,}971 \text{ c. ft. and } \frac{153{,}600}{17} = 9035 \text{ c. ft.}$$

The above presupposes that the period of distillation is extended or abridged, as the case may be.

GAS PRODUCTION.

The carbonization or destructive distillation of the coal for the production of gas is accomplished in the retort-house.

This, the first process in gas making, is also the most important. Any want of economy here (and the word "economy" implies efficient apparatus, proper conditions of working, and good management generally), cannot be compensated for in any of the subsequent processes or stages to which the gas has to be subjected, or through which it has to pass before it reaches the consumer.

In the earliest days of gas manufacture, the retorts, which were of cast-iron, were placed or arranged both in the vertical, the inclined, and the horizontal position.

The vertical retort was the first. This was objectionable by reason of the coal consolidating in a mass, preventing the free exit of the gas, and making it a matter of difficulty to remove the resultant coke.

The other two were an important advance on the vertical form, and were so considered by gas engineers, inasmuch as both the charging and discharging were accomplished with greater ease, and, what is indispensable to prevent loss of illuminating power, an open space was

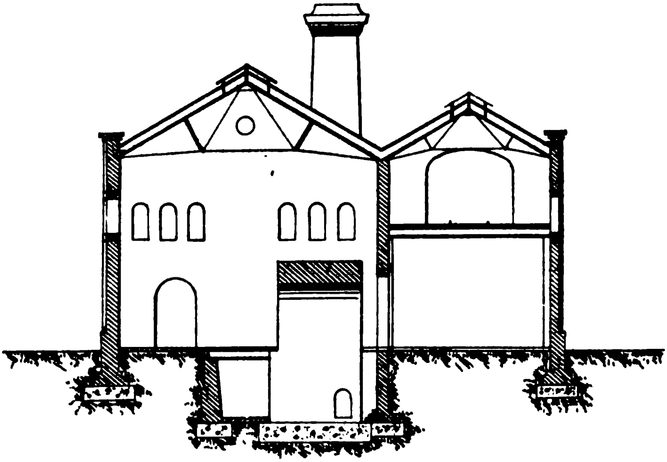


FIG. 3.

left between the coal and the upper surface of the retort for the issue of the gas.

Retort House.—The retort house may be adapted for either a

single (Fig. 3) or double stack of retorts (Fig. 4), and may be of the ground-floor or stage-floor type of erection according to circumstances.

The ground-floor house (Figs. 3 and 4) is the most usual form. In this, the structures and appliances are all above ground, and the process of gas making is conducted on the one floor on which the retort stack and its appurtenances are erected.

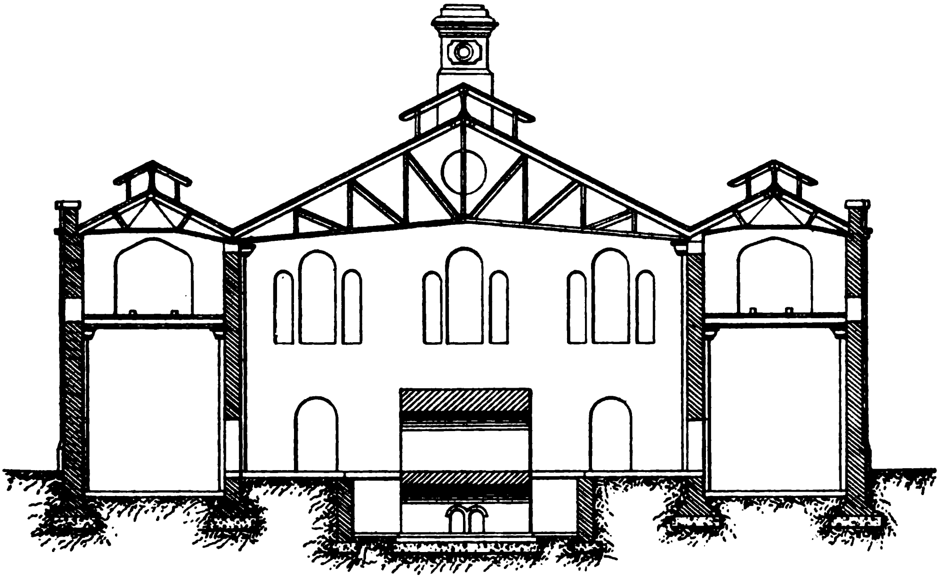


FIG. 4.

Now that generator furnaces for the production of gaseous fuel for heating the retorts under the regenerative system are coming largely into use owing to their proved efficiency, provision is made for them in houses of this class, by carrying the foundation of the retort stack to a depth of at least 9 ft. 6 in. below the ground-floor line, and forming an underground passage about 7 ft. or 8 ft. wide all round the stack if it is a double one, or in front, if single. (See Figs. 3 and 4.)

In all cases of ground-floor houses when the site admits of this arrangement, it should be adopted, and this, too, even in comparatively small works. A house with a provision of this kind may be described as a semi-stage-floor house (Figs. 3 and 4).

The stage-floor house proper (Fig. 5) has not only a ground-floor,

but a stage-floor at an elevation of 10 ft. or 12 ft. above the other. From this latter the retorts are charged and drawn, the hot coke being discharged through suitable openings in the stage-floor on to shoots,

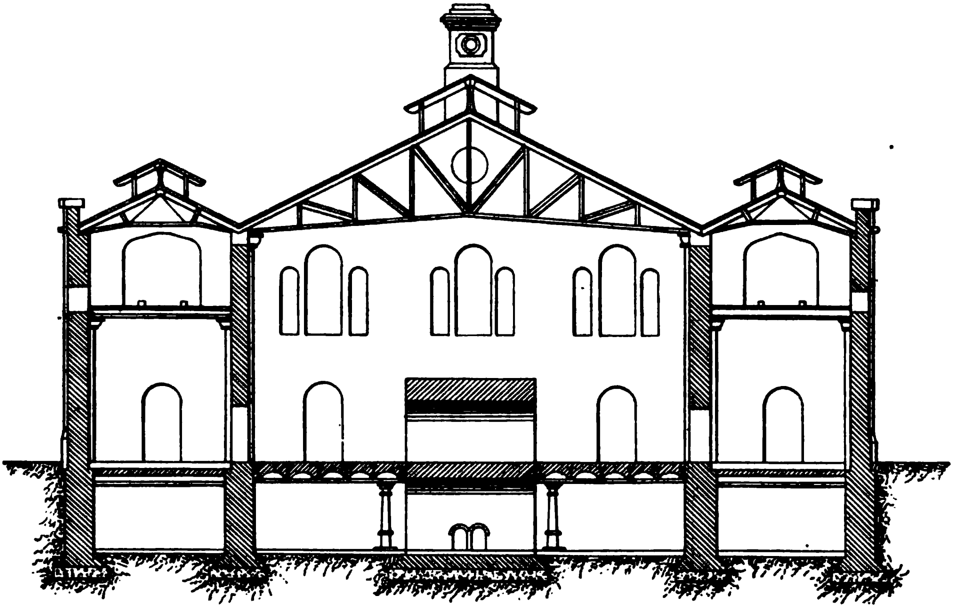


FIG. 5.

and thence to the floor underneath, where it is slaked, and whence it is wheeled or otherwise conveyed away into the coke yard.

A house of this kind costs considerably more than a ground-floor, or semi-ground-floor, house; but, in large works especially, it can be operated with more economy, and the advantages it offers for the removal of the coke, the application of the regenerative system, and in other ways, are very great.

Suitable openings are left in the walls of the retort-house at a height slightly above the stack, for the admission of air and light. The ventilation should be good, and, with that object in view, the louvre should extend from one end of the roof to the other, and be of ample capacity. Ventilating tubes or towers are sometimes used alone or in addition to the louvre ventilator. These are efficient and present a good appearance.

The clear space in front of a retort stack should not be less than 18 feet. When it is intended to employ machinery for charging and drawing the retorts, 22 feet is required.

For convenience in hand-charging and drawing, a slight inclination —say 6 in. to 9 in. in the whole width—towards the stack, should be given to the floor. This allows the waste water from the slaked coke to run into the ash-pans, and is also handier for the stokers in charging.

About 8 feet of the width of the floor, immediately in front of the stack, may be laid with cast-iron plates, or paved with fire-bricks set on edge; the remainder of the floor flagged with 4-inch flags. Blue Staffordshire bricks or tiles, 4 inches thick, make an excellent paving for a retort-house floor; and, when these are used, the fire-bricks in front may be dispensed with.

In a house intended for inclined retorts (Figs. 6 and 7), the conditions of size differ from the others. Here the height is greater, and the width varies according to the length of the retorts, whether 12 ft., 15 ft., 18 ft., or 20 ft., and as to whether it is required to contain a

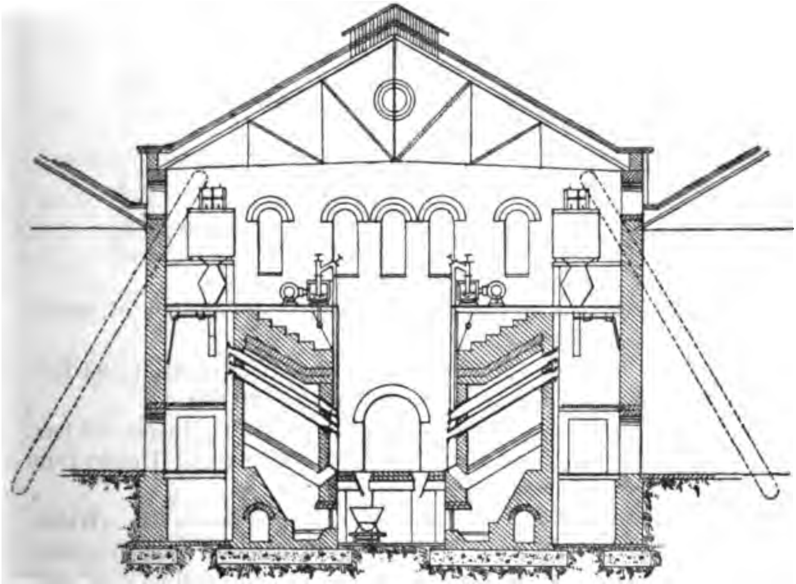


FIG. 6.

single stack, or two stacks of settings face to face (Fig. 6), or back to back (Fig. 7). We prefer Fig. 6, as admitting of better ventilation on the higher operating floor. On this floor, with back-to-back retorts, the heat is often unbearable.

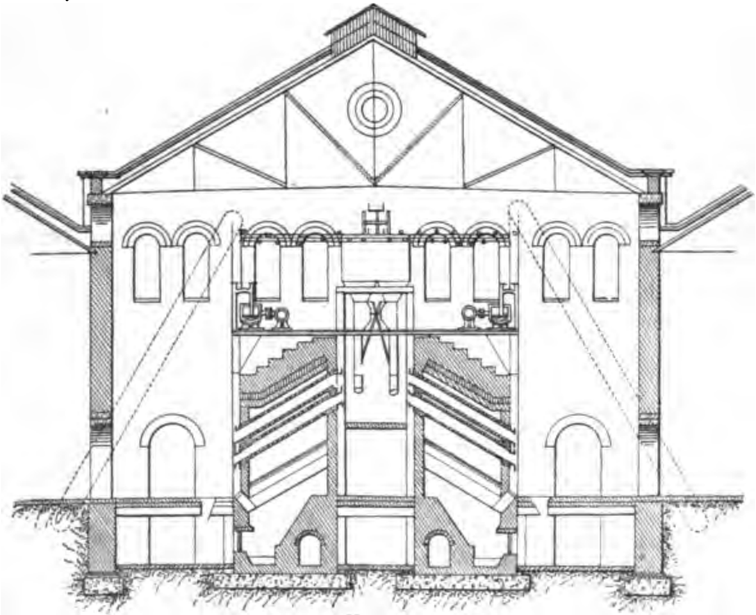


FIG. 7.

The following may be taken as convenient dimensions of retort-houses of the different types:—

House for a single stack of horizontal retorts—Width, inside, 30 feet. Height from charging floor to springing of roof, 20 feet.

House for a double stack of horizontal retorts—Width, inside, 60 feet. Height from charging-floor to springing of roof, 28 feet. Height from basement floor to springing of roof, 38 feet.

House for two stacks of 18 *feet inclined retorts, set face to face*—Width, inside, 84 feet. Height from discharging mouthpiece floor to springing of roof, 38 feet. Height from basement floor to springing of roof, 48 feet. Width of floor space between the two stacks, 30 feet. Width of stack, 15 feet; space at back, 12 feet.

When designing a House for inclined retorts, recently, the writer made an opening six feet wide, running the length of the house, in

the coke discharging floor, to admit of the effectual ventilation of the basement. This can be done in inclined retort houses where the room required in front of the benches is less than in a house with horizontal retorts. A protecting hand-rail extends on both sides of the opening.

Where elevating and conveying machinery are used, the walls in each case require to be about 32 feet high from charging floor.

Wrought-iron or steel, trussed, or arched roof, with ventilator, and slated, or covered with corrugated-iron sheets.

Corrugated-iron sheeting, being lighter than slates or tiles, admits of the principals and purlins being placed wider apart, so reducing their number. The first cost of a roof of this description is less; it is less affected by wind; but its durability is inferior to a slated roof. The sheets should not be thinner than No. 20 gauge.

Retort Stack.—This necessarily varies in size and general construction according to the number of retorts, their dimensions and arrangement in the setting.

In the smaller works a single stack suffices—*i.e.*, a series of ovens or benches about 10½ feet in depth, containing settings of three, five, six, or seven retorts in an oven; the retorts being 9 feet long each.

In the larger works the stack is double, and contains settings of six, seven, eight, or nine retorts, 20 feet long; either "throughs," or made single by being blocked in the centre. In some large works as many as ten and eleven retorts are set in one bed, with an elevated travelling stage in front from which the higher retorts are charged and drawn.

The following details will be found adequate for the erection of a stack with benches of seven large retorts of any shape, and either single or throughs, set as shown in Fig. 8.

The ovens are 8 ft. 6 in. wide, 8 feet high from floor-line, and 20 feet through, inside measure.

Height to top of bench, 10 ft. 3 in.

Excavation for bench, 3 feet deep. For generator furnaces, 9 ft. 6 in. deep.

Place therein bed of hydraulic lime or Portland cement concrete, 14 inches thick.

Upon this build the brick footings of the division walls of ovens, of good hard common bricks, set in lime mortar.

When these are built, fill up between with a further layer of concrete, 18 inches thick.

Division walls of ovens above footings, 18 inches thick, built of best fire-clay bricks, set in fine, well-tempered fire-clay.

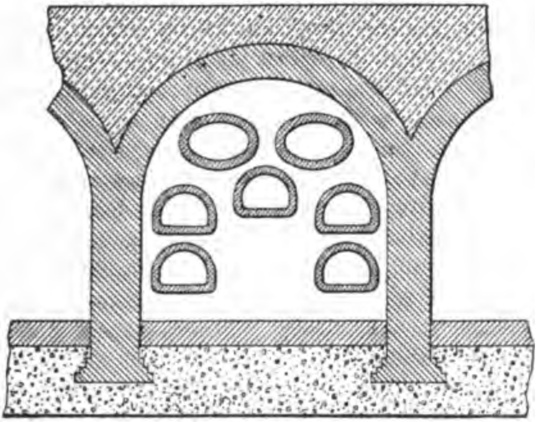


FIG. 8.

Floor of ovens paved two courses on edge with fire-bricks set in fire-clay.

Arched roof of ovens, 14 inches thick, formed of three rings of fire-bricks moulded to the proper radius set in fire-clay.

Two flue-holes in crown of arch, 12 inches square, communicating with main flue on stack. Damper tiles to be provided for these, 27 inches long, 16 inches wide, 3 inches thick. When the main flue is underneath the stack, the flue-holes in crown of arch are not required.

End or buttress walls of stack, 3 ft. 4½ in. thick, of common bricks, built in with the fire-brick work of stack, and faced with fire-bricks laid in good lime mortar.

The whole of top of stack haunched up five courses above the top of the arches, so as to make the total height of 10 ft. 3 in. from floor-line, of good common bricks faced with fire-bricks, laid solid, with close joints, in good lime mortar. Finish with cornice or coping.

Following the example of M. Coze, of Rheims, settings of seven or eight retorts placed at an angle of about 32 degrees have been adopted

by various engineers in this country. These admit of the charge of coal and the discharge of the coke being accomplished with great facility, and with an absence, or at least a minimum, of skilled labour; advantage being taken of the natural slope or angle of repose of the coal, and the law of gravitation, to effect the purpose desired. (Figs. 6 and 7.)

The retorts employed are of the D-shape, tapering usually from 21 × 16 inches diameter at top, to 23 × 16 inches at bottom, and in length from 12 to 20 feet, with a mouthpiece at each end, the gas being taken off from the lower mouthpiece.

The larger pieces of coal are reduced in size by being put through a breaker working in a pit in the coal store. The material is then elevated by mechanical means and discharged into a hopper or hoppers, whence it descends by way of movable charging shoots into the retorts.

In the original Coze system, the mouthpieces are a prolongation of the retorts, and are bent upwards, all reaching the same level. The fall of coal, therefore, from the tipping trucks takes place from one uniform level, which is 8 ft. 4 in. higher than the bottom tier of retorts, 6 ft. higher than the middle tier, and 3 ft. 9 in. higher than the top tier.

It is evident that if a drop of 3 ft. 9 in. is right for the higher tier of retorts, one of 6 ft. and 8 ft. 4 in. cannot be right for the middle and bottom tiers, the retorts all being inclined at the same angle. As a matter of fact, irregular charging is the result.

To overcome these objections, baffling plates are now applied in the shoots to break the force of the stream of coal, and other expedients have been adopted, which have mitigated the drawbacks named.

Mr. Shoubridge, in his charging apparatus, has successfully met the difficulties. In this, the coal contained in the travelling hopper or box is brought down to three different levels, to suit the heights of the three tiers of retorts. The shoots, also three in number, are ranged to meet the same conditions. In addition to these he has an adjustable door at the charger mouth, by which the area of the opening can be varied to suit the conditions of size and dryness or dampness in the coal.

The initial and regulated impulse, due to gravity, which the coal receives in its descent from the hopper and through the charging

shoots, causes it to spread and extend in a uniform layer along the floor of the retort from top to bottom.

The regenerative system of heating is invariably employed for these settings.

The advantages of the inclined or sloping retorts are so manifest and great that their universal adoption is only a question of time.

Retorts.—The materials of which retorts for the distillation or carbonization of coal are made, are fire-clay, either moulded in one piece, or built up in sections, and cast-iron.

In the early days of gas-lighting, and for many years later, cast-iron retorts only were used. The fact of the iron retorts not being capable of standing a heat sufficiently high for the distillation of coal in the most economical manner, and their liability to rapid oxidation and even fusion in the furnace, operated to cause the adoption of clay in the manufacture of retorts.

Cast-iron retorts are now only employed in the very smallest works, where the gas making is intermittent; here they are useful, as they bear letting down frequently without suffering damage. As carbonizers they are not economical, because the heat which they will stand is not high enough to produce the best results in the yield of gas from the coal. The round, 15 inches diameter, and D-shaped, 15 × 18 inches, are the handiest, and 7 ft. 6 in. is a convenient length. They are usually made 1⅜ inch thick, with an ordinary flange, to which the mouthpiece is attached. Their weight is 16 to 18 cwt.

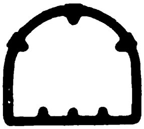


Fig. 9.

Fraser's ribbed retort (Fig. 9) is an improvement on the ordinary form.

Clay retorts, in the face of much prejudice and opposition at first, gradually advanced in popularity as their merits became known, until at the present time their use is almost universal. Single clay retorts are burnt better and more uniformly when the ends are left open in the kiln; the backs are easily jointed in setting, care being taken to butt them close up against the wall. The clay retorts employed are either round (Fig. 10), oval (Fig. 11), or D-shaped (Figs. 12 and 13) in cross-section, their usual diameter being respectively 16 inches or 21 × 15 inches. The round, by reason of its shape, is the strongest and most durable; but it is not equal to the others as a carbonizer.

Clay retorts are usually made 3 inches thick; the flange or swelled portion to which the mouthpiece is bolted being 4 inches

thick, and 8 inches broad, the neck tapering to the thickness of the body.

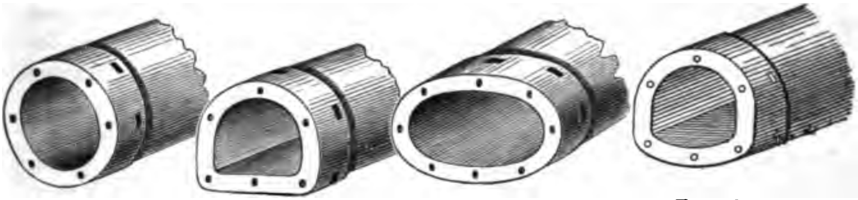


FIG. 10. FIG. 12. FIG. 11. FIG. 13.

The following are useful and convenient sizes of clay retorts :—

Round . . 16 in. diam.		
Oval . . 21 × 15 in. ,,	}	Inside measure, and 10 ft. long outside.
D-shaped, 21 × 15 in. ,,		

The weight of a clay retort of the above sizes is from 14 to 16 cwt.

For very small works the following sizes are more suitable :—

Round . . 14 in. diam.		
Oval . . 18 × 14 in. ,,	}	Inside measure, and 9 feet long outside.
D-shaped, 18 × 14 in. ,,		

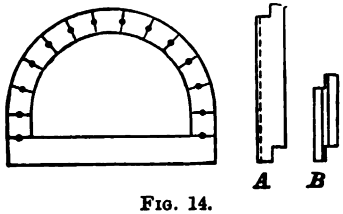


FIG. 14.

Retorts made of fire-bricks and tiles or blocks rebated or grooved together and jointed with fire-clay are extensively in use (Fig. 14). In the matter of durability they possess a clear advantage over the moulded clay retort, their life being three or four times that of the other; and though their first cost is more, this is compensated for by the saving in wear and tear.

Large retorts of this class, 30 to 50 inches wide, which at one time were common enough, are objectionable for many reasons. A large area is exposed to the cold air every time the charge is drawn, and the time occupied in drawing them is necessarily considerable. Again, there is a tendency to allow carbon to accumulate in such retorts, because in the ample space the inconvenience of the presence of a thick body of carbon is not felt by the men in drawing and charging. If the required temperature, however, is kept up under these circumstances, it must be at an excessive expenditure of fuel and labour. The greater depth of the coal, and the constant inequality of carbonization

between the inner and outer portions of the charge, is also a serious drawback to their use.

Retort Settings.—The first and indispensable requisite for good retort setting is to ensure a solid foundation. Nothing will atone for the want of this. It should also be dry, otherwise heat will be abstracted from the furnace.

The joints of the brickwork should be made with fire-clay mortar; they should be as close and fine as it is possible to make them. Each brick should be dipped in water, placed in position, and then gently but firmly bedded home.

The retorts in a setting should be supported by transverse walls resting on a solid foundation, so that they may satisfactorily bear the strain of working during the time they are expected to last. It is an error to suppose that the brickwork causes a diminution in the heat. Take the case of two benches of retorts set, the one with as much brickwork as is required for proper support without obstructing the draught or unnecessarily covering the retort surfaces; and the other having the least possible quantity of brickwork, supporting (say, for example) the retorts only at their extremities. In getting these benches in action for the first time there can be no doubt the latter would be the first to attain the desired temperature; but although the former would require a little longer time, and the expenditure of more fuel at first, the superior regularity of its action over the other in distilling the gas from the coal will scarcely be questioned.

No doubt the thinner the retorts themselves, compatible with strength, the better, so that the heat may the more readily pass to their interior. But the circumstances attending the retort as the vessel containing the material for distillation are not to be confounded with those appertaining to the adjacent brickwork. This need not be more than is reasonable, but it is better to err on the side of excess than too little.

When the retorts are "through" they are usually in three pieces, jointed together, and have a mouthpiece at each end. The advantages gained in using this kind of retort are important. The accumulation of carbon is less, owing to the absence of backs. The current of air which is drawn through their interior every time they are charged tends to loosen any carbon deposit that takes place. More heating surface for carbonization is obtained without additional expense, and

that in the hottest part of the oven. They are also drawn with greater facility. The scoop (Fig. 35, p. 69) is generally used in charging these retorts. As they have to be drawn and charged at both ends simultaneously, they cannot, where the scoop is used, be conveniently worked where the stokers are fewer than six in number.

Dimensions for a setting of three large sized clay retorts, 8 ft. 6 in. long :—

Width of oven, 5 ft. 2 in.; height, 6 ft. 3 in.; depth, 8 ft. 7 in.
Width of furnace at grate bars, 9 in.
Width of furnace at springing of arch, 16 in.
Length of furnace, 30 in.
Height from floor-level to underneath the flanges of the two bottom retorts, 2 ft. 8 in.
Number of grate bars, two; 30 in. long each, made of 2 in. square bar-iron.

Dimensions for a setting of five large sized clay retorts, 9 ft. 4 in. long :—

Width of oven, 8 ft.; height, 7 ft. 6 in.; depth, 9 ft. 5 in.
Width of furnace at grate bars, 10 in.
Width of furnace at springing of arch underneath the middle retort, 18 in.
Length of furnace, 30 in.
Height from floor-line to underneath the flanges of the bottom retorts, 2 ft. 8 in.
Number of grate bars, two; 30 in. long each, made of 2 in. square bar-iron.

Dimensions for a setting of seven large sized clay retorts, 9 ft. 4 in. long :—

Width of oven, 8 ft. 6 in.; height, 8 ft.; depth, 9 ft. 5 in.
Width of furnace at grate bars, 12 in.
Width of furnace at springing of arch, 20 in.
Length of furnace, 36 in.
Height from floor-line to underneath flanges of two bottom retorts, 16 in.
Number of grate bars, three; 36 in. long each, made of 2 in. square bar-iron.

A setting should never, when it can be avoided, be put into action immediately on completion, as the application of strong heat to the damp clay is liable to crack and open the joints and cause "short circuiting," besides destroying the brickwork. The setting ought to be allowed to stand at least fourteen days, in order that it may be gradually dried and hardened. A slow fire should then be lighted in the furnace and kept going for another fourteen days to complete the drying process, the damper to main flue being entirely closed, but the feeding door and the sight and hand holes kept fully open.

On putting the bench or oven into action, the heat should be applied gently at first, the damper being gradually opened a little more each day until the proper temperature is attained. When the retorts have reached a dull red heat, a light charge of coal thrown into them assists the development of the required temperature, and tends to preserve them in good condition. By careful attention to these points, the cracking of clay retorts on first "gaiting" may be entirely avoided.

A cutting heat from the furnace can be prevented, or greatly modified, by having ample nostrils in the furnace arch. There should, therefore, be no undue contraction of the nostrils. It is here where the evil in some settings exists, obstructing the passage, producing cutting draughts, and hastening the destruction of the brickwork. With ample space for the exit of the hot gases or flame from the furnace or combustion chamber into the oven and through the flues, the best results, both as regards heating and economy of fuel, are obtained.

To prevent radiation, the front wall of the oven should be a brick and a half, or 14 inches, thick; the division walls between the ovens two bricks, or 18 inches, thick; the back wall, where the retorts are not "throughs," 14 inches thick.

The duration of clay retorts greatly depends on the setting. When the retorts are properly supported, and suitably protected at points from the cutting heat of the furnace, they will last for two or three years; otherwise, and this is nearer their average life, they will be burnt out in fifteen to eighteen months.

A setting will break down not only from wear and tear and high heats, but owing to the contractility of the materials composing it. The lesson to be drawn from this is that only such materials as are thoroughly shrunk by hard firing should be used.

In moderate sized works, where coke firing is employed, each single horizontal retort should be of capacity sufficient to hold a charge of from 2¾ to 3 cwt. of coal; and with five or six hours' charges the yield per mouthpiece with good bituminous coal should be at the rate of 5500 to 6500 cubic feet per diem of twenty-four hours.

Where heating by regenerative furnaces is adopted, the charges may be heavier or more frequent; and the twenty-four hours' yield per mouthpiece will range from 7000 to 9000 cubic feet, according to the quality of coal used. Even this yield is exceeded by the inclined retorts when their length is 18 or 20 feet and they are heated and worked under the best conditions.

Now, eighteen months' continuous production at the rate of, say, only 6000 cubic feet per mouthpiece per day, is equal to a total production of about 3¼ million cubic feet of gas.

The carbonizing temperature of clay retorts ranges from 2010° Fahr. (orange) and upwards.

The following table by Pouillet gives the colours corresponding to various high temperatures :—

		Fahr.
Faint red		977°
Dull red		1290°
Brilliant red		1470°
Cherry red		1650°
Bright cherry red		1830°
Orange		2010°
Bright orange		2190°
White heat		2370°
Bright white heat		2550°
Dazzling white		2730°
Melting point of cast-iron—		
White	1920° to	2010°
Grey	2010° to	2190°

The effect of an excessively low heat in the retorts is to diminish the gaseous products, the chief result of the distillation being the production of tar.

In setting iron retorts a space of about 3 inches should be left in the rear, to allow for the expansion of the metal and prevent their being forced out beyond the front wall, with the possible breakage of the ascension-pipes. Fire-clay tiles are invariably used to protect iron retorts from the direct action of the furnace heat. Oxidation proceeds

rapidly on their uncovered surface, and the scale should be frequently removed, otherwise the proper temperature will not be maintained. For facility in doing this, sight holes should be left in convenient positions in the front wall of the bench. They should always be scurfed before being let down, otherwise the unequal contraction of the incrusted carbon and the metal of the retort in cooling will cause fracture in the latter. The duration of an iron retort is equal to the production of about 700,000 to 800,000 cubic feet of gas. The best temperature for them is that ranging from 1650° Fahr. (cherry red) to 1830° Fahr. (bright cherry red). Any temperature beyond this is apt to burn or soften, and so cause distortion of the retort.

The Regenerative System of Heating Retorts.—The use of gaseous fuel for heating retorts has made rapid progress of recent years. From a scientific point of view generator (Figs. 15, 16) and regenerative furnaces (Fig. 17) have everything to recommend them. The saving in fuel by their adoption is considerable, even on the best results obtained by direct coke firing, but they offer other marked advantages. "Clinkering" at the base of the retorts is avoided, and consequently wear and tear of settings is reduced; the heats are higher and steadier, and being more easily regulated they save manual labour; the coal is carbonized more rapidly, and thus charges of shorter duration can be employed, increasing the production of gas per mouthpiece and economizing space in the retort house.

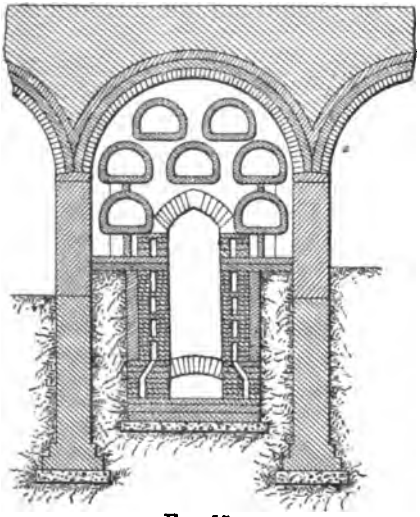


FIG. 15.

In the generator furnace, the solid fuel is converted into carbonic oxide gas, CO, and if the regenerative system is not superadded, the gas produced is mixed with the entering air whilst the latter is at the ordinary, or at but a slightly higher temperature, unassisted

by the waste heat from the flue. In some instances where the air is heated, the heat is derived from the active heat within the furnace, and so to this extent (as compared with the regenerative method) detracts from the temperature therein.

In the regenerative system invented by Siemens, the hot furnace gases, after they have done their work in the oven, and which, under ordinary circumstances, are allowed to escape up the chimney, are utilized in heating the air required for combustion.

There is quite a variety of generators in actual use, and though they vary in the details of their construction, and in their position either within the arch of the retort bench or outside of it, the principle of action in each is identical.

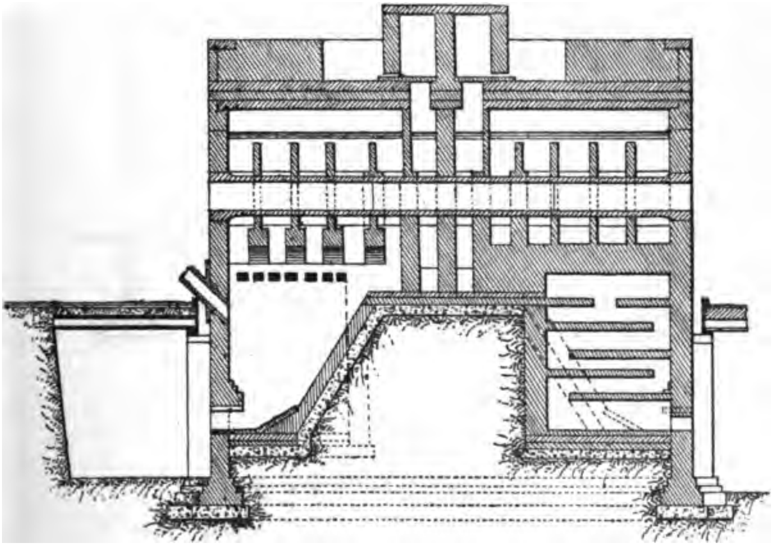


FIG. 16.

Mr. Webber gives the following concise description of the generator: "There is much difference in the details of generator furnaces as at present constructed by various engineers; but their main features are always alike, and are remarkably simple. The usual form of the generator itself is that of a kiln, generally sunk underground or beneath the level of the charging floor of the retort house; the capacity of the kiln, of course, varying with the amount of work it is intended to

perform; but it is usually about one and a half diameters in height. The form of cross-section of the generator may be either rectangular or round, the former being easier of construction, although, according to Grahn, the latter gives better results. The generator is fed through

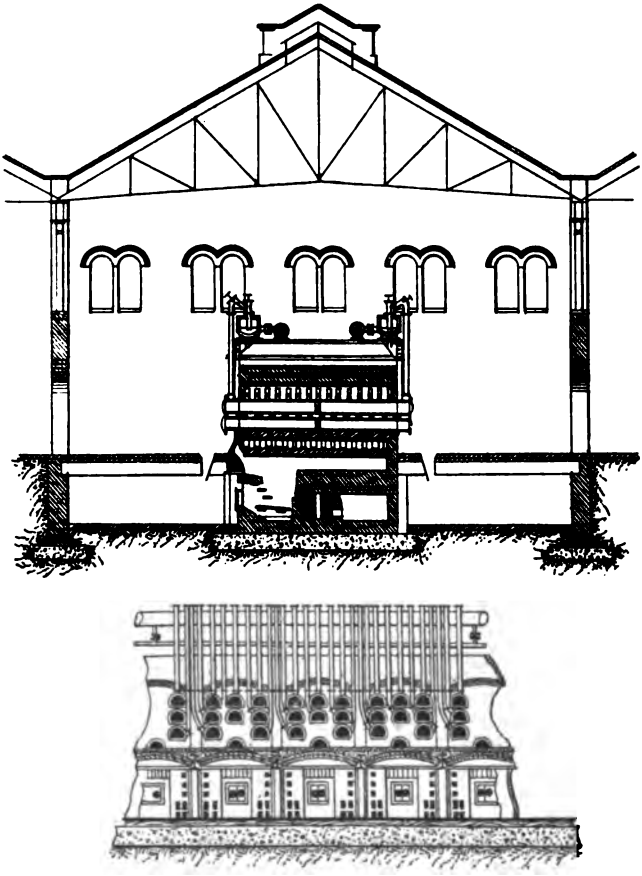


FIG. 17.

a hole in the top, covered with an air-tight cap. The gas is usually taken off by an opening near the top. The lower part of the generator, in which the initial combustion commences, is subject to the greatest wear, especially from the formation of clinker. The air is admitted

either by a grate at the bottom of the generator, as in an ordinary furnace, or by openings in the brickwork, which may be either at the sides or in the bottom—which in that case is tapered down to the size of the opening—or by a combination of the two, as designed by Liegel, who puts a fire grate underneath the opening in the bottom of the generator. . . . . . The generator should be lined with at least 9 inches of the best fire-bricks, between which and the surrounding walls of common brickwork, about 18 inches thick, a space of about 6 inches is left to be filled with a comparatively non-conducting material, such as asbestos, or even powdered fire-bricks, in order to diminish the loss of heat by radiation.

"The gas channel, by which the products of combustion leave the generator, varies, according to circumstances, from a short connecting chamber to one of considerable length; but the former, or some similar plan, is obviously preferable when it is convenient to adopt it. In all cases the passage, when of any length, must be provided with a damper.

"In most cases a generator is about 8 feet to 8 feet 6 inches square, which is sufficient for heating two large settings of retorts. For one setting half this area will suffice. The body of incandescent coke is usually about 8 feet deep, although it might be reduced to half that depth without vitiating the gas produced; still it is best to keep a considerable margin, in order to avoid risk of interruption in working, which might otherwise be caused by irregularity in charging the generator, which operation would, with the sizes of apparatus above specified, be necessary at four or five hours' intervals.

"The generator may be situated anywhere in the neighbourhood of the retort bench. The furnace gases are admitted to the interior of the retort stack, guarded as much as possible from loss of their acquired heat while in transit, and there mingle with the proper quantity of previously heated air, the mixture being attended with instant combustion." *

On the principle of regeneration, as applied to the heating of retorts, it may be pointed out that dry air, though diathermanous to radiant heat, takes up heat with extreme rapidity when brought in contact with a hot surface. It is not necessary, therefore, that the hot flue passage through which the secondary air is caused to travel in

* "King's Treatise on Coal Gas," Vol. III., p. 879.

order to be heated before coming in contact with the combustible gases from the generator, should be long-extended and tortuous in its course.

The advantages of the so-called regenerative arrangements as applied to retort furnaces, are due not only, or chiefly (though this is important), to the heating of the secondary air, which is readily accomplished, but largely to the circumstance that the heat of the waste gases, as the latter traverse the passages constructed alongside the furnace, is at a potential higher than that to which the brickwork in the base of the setting, and in the sides of the generator in the absence of the waste gas flues, could possibly attain. The effect of this is to insulate, as it were, the heat of the furnace, minimizing outward radiation and conduction.

Heat, like water and electricity, tends to establish an equilibrium; and the lower the temperature of a body in contact with another at a higher temperature, the greater the abstraction of heat from the latter by the former.

From this it will be evident that the function fulfilled by the heat of the waste gases cannot properly be considered as "regenerative," in the strict sense of that word. Their temperature is necessarily lower than that of the furnace and the inside of the oven. Heat cannot travel from a lower to a higher potential any more than water under normal conditions can travel uphill, and therefore it is not possible for the lower temperature to "regenerate" the higher. The chief function of the heat of the waste gases is by insulation, as already explained, to conserve, in the ratio of their own temperature, the heat generated by combustion in the furnace. If it were possible to enclose the heated ovens of a retort stack on all sides with an envelope of heat, it is obvious that the heat of the ovens would be conserved, a higher and steadier temperature maintained, and that economy of fuel would result.

At the risk of some repetition, it may be pointed out that the secrets of success in generator furnace-building and retort-setting, are:—

(1) To make sure that the system adopted is a good one.
(2) To ensure a sound, unyielding and dry foundation.
(3) To use only the best materials and workmanship.
(4) To have the joints of the brickwork throughout as thin and close as possible.

And in the working of these :—

(1) To get up the heat very slowly and gently at the outset, drying the brickwork gradually and thoroughly at a low temperature.

(2) To charge the generator with hot coke as drawn from the retorts.

(3) To carefully regulate the primary air supply, and keep the ash pans full of water.

(4) To insist on the generators being kept full of coke. If this is not done, CO_2 instead of CO will be produced in them, the concentrated heat melting down the brickwork, instead of doing good service in the ampler area of the retort oven. The generators should be filled up every time the retorts are drawn.

If a gas manager has complaint to make of the regenerative system and settings and their results, then, one, or other, or all of the above points have been neglected.

Flues and Draught.—For a double stack containing eight or ten ovens or benches on each side, the main flue should also be double, and the internal dimensions of each division not less than 36 inches in depth by 15 inches in width. For even a less number of ovens, the size of the flue should not vary greatly from the above.

An insufficient draught, whilst it invariably results in diminished heats, causes a waste of fuel, from the consequent incomplete combustion in the furnace, and the usual hard firing that accompanies it. The flame which is occasionally seen at the top of a retort-house chimney is significant of this defect. The flame is produced by the unconsumed carbonic oxide uniting with its due proportion of oxygen on coming in contact with the atmosphere, and, by combustion, being converted into carbonic acid. When the proper quantity of air is supplied to the combustion chamber, the carbonic oxide produced is there converted into carbonic acid, and the heat thus generated is utilized for the distillation of the coal contained in the retorts.

An excessive draught through the ovens is to be avoided, as well as an obstructed one. If too much air is drawn in, its effect is to reduce the heat, as well as to cause the consumption of an excess of fuel. Hence the importance of being able to control the draught by means of a damper placed at the entrance of the cross flue into the main flue of the bench.

According to the experiments of Dulong,

1 lb. of hydrogen, burning to water,		yields 62,585	units of heat.
1 ,, ,, carbon,	,, to carbonic acid,	,, 12,906	,,
1 ,, ,, carbon,	,, to carbonic oxide,	,, 2,495	,,
1 ,, ,, carbonic oxide,	,, to carbonic acid,	,, 4,478	,,

Note.—The English standard unit of heat is the quantity of heat necessary to raise the temperature of a pound avoirdupois of water 1° Fahr. The French *calorie* is the quantity of heat required to raise 1 kilo. (2·2 lbs. avoirdupois) of water 1° Centigrade.

As a rule, when firing with coke, cleaning off the fire bars once in 12 hours is sufficient. Too frequent cleaning entails a waste of coke, besides reducing the heat of the oven.

Instead of the tall chimney-stalk at the end of the retort house, it is the custom to erect chimneys or shafts of less altitude immediately over the bench, or between the benches, rising a few feet above the roof, and serving for four or more double ovens on each side. These are found to produce a sufficient draught, they are more uniform and regular in their action, and their cost is necessarily less. But as they deliver the products of combustion into the atmosphere at a low level, their use should be restricted to neighbourhoods where the nuisance is unobjectionable.

When the room can be spared, it is best to erect the chimney between, and apart from, the retort benches; so that when the latter need to be taken down and rebuilt, the chimney, being a more permanent structure, remains undisturbed.

Sometimes each bench is supplied with a small shaft for its own use. In some American gas-works the main flue and chimney are dispensed with altogether, the opening in the crown of the bench being found sufficient, it is said, to afford the requisite draught. Even assuming the draught; under such conditions, to be ample for ensuring perfect heating and carbonization, which may be doubted, the objections to allowing the hot fumes to escape into the retort house underneath the roof, are sufficiently obvious to cause the practice to be condemned.

The following is a useful rule for determining the size of the vertical opening in retort-house chimneys about 70 feet in height: Allow 1½ square inches of area for each lineal foot of retort, or, say, 15 inches per mouthpiece. Example.—Required the internal sectional area of a chimney-stalk serving ten double benches of eight retorts, or

sixteen mouthpieces each, five benches on each side of chimney; retorts 20 feet through, total, 160 mouthpieces: Then—

$$160 \times 15 = \frac{2400}{144} = 16{\cdot}66 \text{ square feet area.}$$

Analysis of Furnace Gases.—For ascertaining the composition of the spent furnace gases from retort settings, Bunte's gas burette is well adapted. A wrought-iron tube is employed for collecting the sample. This is made to project into the centre of the flue, and is continued for some distance outside, so as to cool the gas. The better to obtain an average sample, it is well to aspirate a much larger quantity of gas than is required, and take off the sample simultaneously by a branch tube.

The constituents it is chiefly necessary to determine are carbonic acid and oxygen. The former is absorbed by caustic potash, the latter by pyrogallate of potash. For details of the manipulation, Hempel's or Winkler's works on gas analysis should be consulted.

Should it be also required to determine the amount of carbonic oxide, and especially for the analysis of combustible producer gas, Orsat-Muencke's apparatus is more suitable. The latter operation is, however, seldom carried out, as the composition of the spent gas, or products of combustion, affords a good indication of the efficiency or otherwise of the furnace and setting.

Under good conditions the spent gas should not contain less than 15 or 16 per cent of carbonic acid, nor more than 1, or, at most, 2 per cent. of oxygen.

Carbon Deposit.—In the distillation of coal a deposit of carbon takes place within the retorts, which, if allowed to go on accumulating, eventually seriously contracts their internal area, and causes a diminution in the heats.

This deposit is due principally to the pressure produced by the resistance offered to the passage of the gas through the different apparatus.

Its removal by scurfing with chisel bars in the ordinary way is always more or less attended with damage to the retorts; the more so as they require to stand off for 6 or 12 hours, to loosen the carbon by the admission of air, before applying the bar.

Different methods of scurfing have been tried with varying success; the best probably being that by which a current of air and steam is

made to impinge upon the carbonaceous deposit; but, after all, the best plan of obviating the difficulty is to prevent the deposit as much as possible, by minimizing the dip, by employing an exhauster to reduce the back pressure; and by frequently scurfing the surface of the retorts with a rounded steel scraper.

In the slaking or quenching of hot coke, water is a necessity. It is true that if the coke is drawn from the retorts into iron barrows, and a close cover placed over it, the confined gases, in the absence of atmospheric oxygen, will gradually arrest combustion in the mass; and this method of dealing with the coke is sometimes adopted with a view to abating the nuisance of the escape of steam charged with sulphurous vapours from the retort house, and to preserve the coke for sale in a dry and bright condition. Where the production of coke is great, however, as in the case of large works, this is an inconvenient, if not impossible, method of dealing with the material.

The quantity of water absorbed by the coke when it is slaked in the ordinary way is comparatively small, not exceeding, on the average, 15 per cent. of the weight of coke in the first instance, and the bulk of this evaporates when the coke is deposited outside the retort house in the open air, about 3 per cent. of moisture being permanently retained.

In moderate sized works, skilfully conducted, about 3¼ cwt. of coke, or 25 per cent. of the production (say, 13 cwt.) of coke per ton from Newcastle and other high-class bituminous coals, is used as fuel to carbonize one ton of coal.

In large works, under the most favourable conditions, and with the ablest management, the consumption of coke for heating the ovens may be reduced as low as 15 to 20 per cent. of the production.

In small works, one-third the production of coke is nearer the average consumption.

Radiation from the benches is reduced, and fuel economized to an extent greater than might be supposed, by temporarily bricking up the furnace doors and the mouths of all retorts in beds not in use, in proximity to others in action.

Where tar is unmarketable, or but of low value, and there is a ready sale for coke, the former should be employed in heating the retorts.

Its application is exceedingly simple. When applied to an ordinary furnace, the ash pan is first filled up with breeze; the door

is then removed and the door space bricked up, leaving two holes, one above the other, about 4 by 8 inches. The tar is supplied through the top hole, the bottom hole being for the admission of air, and to allow of the fire being stirred when required. A piece of 2-in. angle-iron, or a grooved fire-clay slab, or other convenient channel, is inserted into the furnace through the top hole, and down this the tar is made to flow in a stream about 3-16ths of an inch thick. (Fig. 18.)

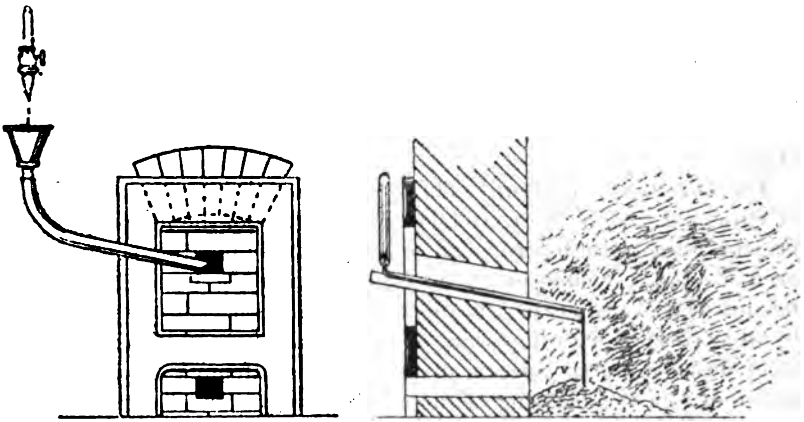


FIG. 18.

The tar can be taken direct from the hydraulic main, or back main, in the bottom of which a 1-in. wrought-iron ferrule, having a stop-cock attached, is screwed. A ½-in. reducing coupling is then put on, and this size of pipe brought down to the side of the oven, where the tar is supplied to the trough through a nozzle of the proper dimensions; or a jet of steam directed through the nozzle may be used to spray the tar into the furnace.

As the hydraulic and back mains will not supply all the tar necessary, a pipe should also be brought from a tank or cistern erected in some convenient place outside the retort house. If this tank is placed inside the retort house, the dust arising from the coal mixes with the tar and hinders its flow. Into this tank a supply of tar should be pumped from the tar well as required.

The objection to the use of tar as fuel, as above applied, is that the intense heat which is generated at the point of combustion

soon destroys the arch or tiles underneath the middle retort, breaking the latter down.

As this retort, in the ordinary setting of fives and sevens, is the one usually first burnt out, it is advisable to restrict the use of tar to those benches that have been at work for a length of time, and in which the middle retort is either much burnt or already destroyed.

Numerous other expedients for firing by means of tar have been put forward, but the above has the merit of efficiency with cheapness and extreme simplicity. In the event of a deficiency in the supply of tar, this furnace is readily reconverted for coke firing.

About 50 gallons of tar used as fuel will carbonize 2½ tons of Newcastle coal, or a mixture of Wigan coal and cannel, in 24 hours.

At this rate about 6 gallons of tar are equal to a sack (3 bushels) of coke.

The Dinsmore System.—This system (so called after its inventor) of enriching gas by the conversion of a portion of the hydrocarbons present in the tar into permanent gas of a high illuminating power, has been adopted at Widnes under the supervision of Mr. Isaac Carr, who has introduced various modifications in the method of its application, by which results of an important character have been obtained. The chief obstacle to the success of all previous attempts in a similar direction was the blocking of the ascension-pipes and hydraulic and foul mains with pitch. This difficulty has now been overcome. With one-third of the carbonizing plant at work on the tar system, about 10,000 cubic feet of gas per ton, of an illuminating power equal to 19 standard candles, are obtained from an inferior class of coal.

Retort Bench Mountings.—The brickwork of the retort stack is braced together with buckstaves and tie rods, applied both longitudinally and transversely, to enable it to resist the expanding action of the heat. The buckstaves are preferably made of wrought-iron or steel, either rolled H (Fig. 19), or rail section (Fig. 20); or formed of two flat bars 6 in. wide and at least 1¼ in. thick, with cast-iron distance pieces between, through which the two flat bars are riveted together with ¾-in. rivets. (Fig. 21.)

The boss A, with hole therein, is intended to receive the wrought-iron pipe, 1-in. diameter, leading from the 3-in. water main on the top of the retort stack. To the end of this pipe a brass swivel is attached, and from this again a piece of 1-in. steam tubing, 11 inches long, projects, having a brass swivel cock at its end; a tube of ¾ of an inch

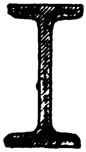


FIG. 19.

FIG. 20.

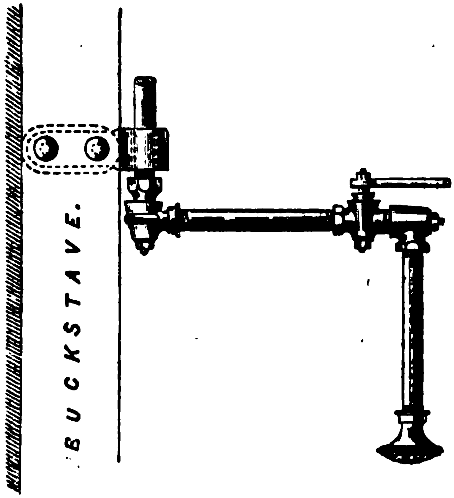


FIG. 22.

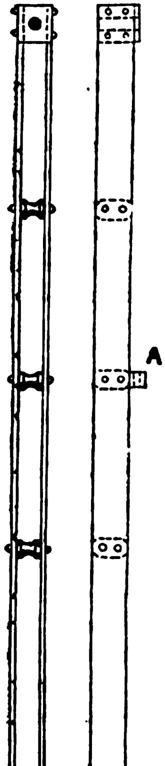


FIG. 21.

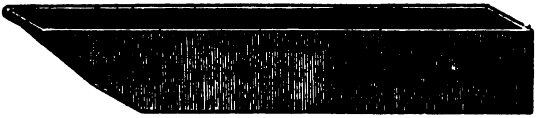


FIG. 23.

diameter is screwed thereto, and terminates in a 4-in. brass rose jet, through which water is discharged for slaking the coke as it is drawn from the retorts. (Fig. 22.)

The tie rods are of 2-in. round or square iron, threaded 6 in. at each end, and furnished with strong hexagon nuts and washers.

A ¾-in. steel plate, extending the width of the stack, and 2 ft. deep, placed in a recess at the end or buttress wall opposite the springing of the arches, and underneath the buckstaves, helps materially to bind the brickwork together, and prevents undue expansion.

The ash pan, where coke firing is employed, may be of wrought plate-iron 5-16 in., or of cast-iron 7-16 in. thick. The usual dimensions are: Length 5 ft., width 12 in., depth 10 in., outside. (Fig. 23.) The pan should always be kept charged with water. The water, heated by the glowing coke, gives off steam in considerable volume, and this, rising underneath and between the furnace bars, contributes to the durability of these by keeping them comparatively cool. In its passage through the hot coke the steam is decomposed into its constituent gases, the hydrogen adding to the furnace fuel, and the oxygen promoting combustion. A tidy fire about, with the ash pan charged with water and reflecting the bright fire between the bars, is one of the indications of good stoking.

The grate bars are two or three in number and 30 in. to 36 in. long, made of 2-in. wrought bar-iron, and supported on two bearing bars 3 in. square in section, 24 in. long, their ends built into the brickwork.

The furnace frame and door (Fig. 18) are of cast-iron, the latter with pocket to receive a tile or fire-brick lining. Cast-iron cleaning-out and sight-hole boxes with plugs are built into the front wall of the setting.

The retort mouthpiece, of cast-iron, is round, D-shaped, or oval, to suit the retort, and 15 in. deep from front to back, with plugs for fastening to the retort with seven ¾-in. bolts. It has a socket to receive the ascension-pipe end, and is furnished with lugs, cross bar, and screw for securing the luted lid, which is of plate iron or steel ½ in. thick, with lug on each side, and dished.

The following are the details of a mouthpiece for an oval retort 21 in. by 15 in., and will serve as a model for any other size and shape, allowance being made for varying dimensions. (See Figs. 24 to 27.)

Depth from front to back, over all, 15 in.
Thickness of metal in front portion, $\frac{5}{8}$ in.
Ditto in lip, 1 in., and planed level.
Ditto in flange, 1 in.
Width of flange in front, $8\frac{5}{8}$ in.
Ditto at back, 4 in.
Number of bolt holes, eight; diameter, 1 in.
Ear-box on each side, with slot 2 in. by $\frac{5}{8}$ in.
Socket, to receive end of ascension-pipe, 5 in. in height, and $6\frac{1}{2}$ in. diameter inside; centre 5 in. from front.
Bolts, for securing mouthpiece to retort, eight; diameter, $\frac{7}{8}$ in.; screwed and nutted at both ends.
Lugs of wrought-iron, 14 in. long, 2 in. broad, and $\frac{5}{8}$ in. thick; one with jaws and pin for hinging cross-bar, the other cranked and notched as in Fig. 27. Slit at opposite end, 2 in. long, $\frac{1}{2}$ in. wide; wedged to ear-box.
Cross-bar of wrought-iron, 25 in. long, 2 in. broad at each end, and $\frac{1}{2}$ in. thick. Middle part $2\frac{1}{2}$ in. broad, swelled out to 2 in. thick, with 1 in. screwed hole through centre.
Screw, 10 in. long, with square thread 7 in. of its length.
Cross handle, 14 in. long, $\frac{3}{4}$ in. round-iron.
Lid, $\frac{1}{2}$ in. thick, plate-iron, dished, with lug on each side.

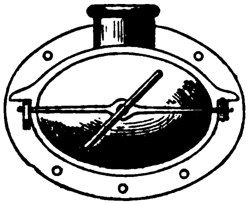


FIG. 24.

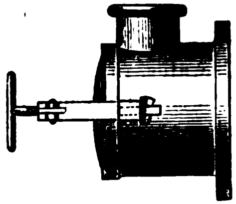


FIG. 25.


FIG. 26.


FIG. 27.

Cements for Jointing Mouthpieces,—

To clay retorts—

Three-fourths by weight of fire-clay.
One-fourth by weight of iron borings.

When ready to connect, mix with ammoniacal water. Use no sulphur.

Or,—

20 lbs. gypsum (sulphate of lime) made into a pulp with water.

10 lbs. iron borings saturated with a strong solution of sal ammoniac.

Mix well together till of a consistency fit for use.

In fixing the mouthpieces to clay retorts, the flange or face of the retort should be notched all over with a sharp-pointed hammer, or a slight channel cut all round (this is best done by the retort maker in course of manufacture), for the cement to bed into when the bolts are screwed up.

For iron retorts—

2 lbs. fine clean iron borings.
1 oz. sal ammoniac.
1 oz. flowers of sulphur.

Mix together and keep dry. When required for use, add water to bring the mixture to a proper consistency.

Besides being fastened with bolts, mouthpieces should always be supported by cross-bars pressing against the flanges, the ends being secured to the buckstaves.

Luting for Retort Lids.—Ordinary lime, or spent lime from the purifiers mixed with fire-clay or common clay, and worked up into mortar.

The following makes a tough persistent luting:—

1 part lime.
2 parts moulding sand.

Ground up together, with water, in a mortar mill.

Self-sealing retort lids are extensively used. This lid is not removed from the mouthpiece in charging the retort, but swivels round with the hinged cross bar, to which it is secured. It is made in any form to suit the shape of the retort, with upturned semi-circular edge, faced true. This pressing against the flat edge of the mouthpiece, which is also faced, makes a gas-tight joint without the intervention of luting.

The ascension or stand pipes may be of cast or wrought-iron, and should not be less than 5 in. diameter. Pipes of 6 in. diameter are commonly adopted.

The best caulking material for ascension-pipes at their junction with the mouthpiece socket, is ordinary ground fire-clay, or slaked lime, made of the consistency of putty. These, when pressed down into the space between the spigot and socket, make a perfectly tight

and durable joint, and are easily removed when the retorts need renewing. On the other hand, when the joints are caulked with iron cement, the labour in cutting it out and the risk of splitting the socket are considerable.

Ascension-pipes occasionally become choked to a greater or less degree with thick tar, pitch, and other carbonaceous matter. When this occurs, it is well to let as many as can be spared at once stand off for a shift (provided the retorts are in condition to admit of this), drawing the charge and removing the bonnet or plug from the top of the bridge-pipe. The heated air making its way through the smallest aperture will thoroughly clear them of the obstruction.

Drawing off the thick tar from the hydraulic main, and allowing free exit of the gas from the latter, and keeping the pipes cool, are the best preventives of choking. This latter may be accomplished to a great extent by making the front walls of the ovens 1½ bricks thick, so preventing undue radiation from the bench, and having the mouth-pieces of the retorts so constructed as to allow of the pipes standing 6 or 8 inches away from the front wall of the oven.

The bridge and dip pipes are of cast-iron and 5 in. is the usual diameter. The bridge-pipes are made in various useful forms

Fig. 28.

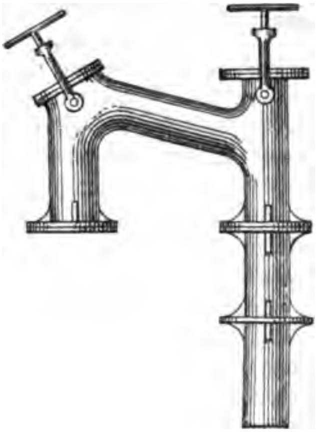


Fig. 29.

(Figs. 28 and 29). The chief consideration in the design should be to secure easy access to their interior for clearing purposes in case of

The quantity of water thus yielded varies with different coals, but the average yield may be set down at 16 gals. per ton. It has previously been explained (see page 15) that a portion of the steam from wet coal is decomposed in the hot retorts, being resolved into its constituent gases. It will be seen, therefore, assuming the correctness of this hypothesis, that two opposite processes are being carried on simultaneously in the retorts—the analytical and the synthetical—and this apparently inconsistent action may be explained by the original character of the substance acted upon—the steam in the one instance, and the gases, oxygen and hydrogen, in the other—and their proximity to, and period of contact with, the hot surface traversed by them.

The strong affinity which exists between this water and the ammonia impurity in the crude gas, causes the absorption of much of the latter by the former, producing what is, roughly speaking, a solution of ammonia. This again, by reason of its affinity for sulphuretted hydrogen and carbonic acid, absorbs a proportion of the gases named, reducing the amount of these impurities in the gas, and thus is produced the complex liquid designated "ammoniacal liquor."

The hydrocarbons contribute largely to the illuminating power of the gas, and it is therefore desirable to retain them in the permanently gaseous form. Some of them, especially such as are of the greatest density, are reduced to the liquid state by the mere mechanical reduction of their temperature; whilst others of equal specific gravity, and many of those of lower density, undergo a change from the gaseous to the liquid condition, by reason of the solvent or absorbent action of the liquid contents of the hydraulic main, through which, by reason of the dip, they have to pass; or with which, in the absence of the dip, they come intimately in contact. The former may be classed as hydrocarbon vapours, the latter as gaseous hydrocarbons. It is thus evident that the process of condensation begins at the hydraulic main, the results there produced materially affecting the quality of the gas.

Those hydrocarbons that are changed to the liquid form by this slight diminution of temperature, it is probably impossible to retain in the gas under any circumstances whatsoever. With the more volatile, though still heavy, hydrocarbons, the case is different; the power of retaining them in the permanently gaseous form is within the bounds of possibility, and these are, therefore, of the greatest interest to the gas manufacturer.

A further class of hydrocarbons are not liquefied at all under ordinary conditions, and there should never be any difficulty experienced in keeping them in the gaseous state.

The retention in the gas of the second class of hydrocarbons—viz., those which, though of high specific gravity, it is practicable to retain in the gaseous state, and how this is most likely to be accomplished, greatly concerns the gas-maker. It has been assumed that the mere reduction of temperature between the retort-mouth and the hydraulic main will not affect their gaseous condition. Under what other circumstances, then, are they condensed in the hydraulic main, and in the subsequent mains leading to the condenser? The answer is clear, and is what has been already indicated—viz., by the affinity which exists between them and the already liquefied hydrocarbons present in the mains.

The cooling of the gas gradually is a provision the wisdom of which is unquestionable, and the plan of causing it to make the circuit of the retort house in pipes is probably the best method of accomplishing that object; but the deposited tar in the hydraulic main and in the foul main at the point, as near as can be ascertained, when its temperature has fallen to about 110° or 100° Fahr.—the temperature at which its absorbent powers come into most active operation—should be drained away direct to the tar-well by its own separate conductor.

The chief advantages believed to accrue from lengthened contact of the gas with the tar are, first, the absorption by the latter of naphthalene that would otherwise be carried forward to be deposited, by reason of the decrease in temperature and other causes, in the mains on the works, and even in the street mains, service pipes, and the internal fittings on the premises of consumers; and, secondly, the absorption also of a considerable portion of the obnoxious sulphur and other compounds.

These advantages will not be forfeited by the direct removal of the bulk of the tar, because sufficient light tar will be left in the circuitous gas main to absorb any excess of naphthalene vapour present, and even to assimilate a portion of the sulphur and other impurities. Besides this, as the general effect will be to leave a larger proportion of the gaseous hydrocarbons in the gas, these, by virtue of the power which they possess in common with the liquid hydrocarbons, of assimilating—and, in this special case, of suspending—other hydro-

carbons, will necessarily assist in retaining in the permanent form a portion of the naphthalene that would, in presence of the greater bulk of tar, have been liquefied and deposited. By a similar train of reasoning, the fact of the inferior quality of the tar produced from the richer cannels, as compared with that from coal, may be explained.

In dealing with this subject, it has been assumed by some that no absorbent action is likely to result so long as the tar with which the gas is in contact is at a temperature of about 100° Fahr., and above; and that, therefore, the dip in the hydraulic main causes no diminution in the amount of hydrocarbon gases present. It has even been assumed that the tar in the main gives off a proportion of hydrocarbon vapour, and in this way increases the illuminating power of the gas. On reflection, however, it will be plain that this argument is altogether untenable, for it is scarcely possible to conceive that hydrocarbons which have already been liquefied at a high temperature, can again, at a lower temperature, assume the gaseous or vaporous form. There can be no doubt that the heavy tars have an absorbent action, less or more, at all temperatures, being greatest at the lowest; and this being so, the passage of the gas through such tars by reason of the dip in the hydraulic main, must have a prejudicial effect upon the illuminating constituents of the gas. On the other hand, where means are employed for removing the heavy tars from the main as rapidly as possible after they are deposited, the disadvantages of the dip into the lighter liquors contained therein are reduced almost to *nil*. This is especially true where the arrangements are such that, by careful adjustment, and an adequate area at the water level, the dip is limited to about three-fourths of an inch.

It is desirable that the ends of the dip-pipes in the hydraulic main should be sealed with the ammoniacal liquor in preference to the tar, the latter not only robbing the gas to some extent of its richest illuminating substances, but offering greater resistance to its passage. Various expedients to accomplish this end have been devised and are in use in well-regulated gas-works.

Livesey and Tanner's Differential Tar and Liquor Overflow and Tar Screen is a useful provision for separating the tar and liquor by means of a perforated screen, preventing the oscillation of the liquor in the main and allowing of a minimum of seal. The arrangement for adjusting the difference of seal required for drawing off the tar

and liquor separately according to their specific gravities, is also very ingenious and useful.

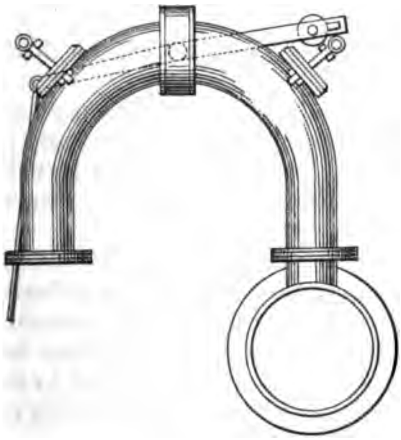


FIG. 84.

The hydraulic main, and consequently the dip or seal, can be dispensed with altogether by employing a bridge-pipe with a wing valve in the centre of the bridge (Fig. 84). This is shut by means of a rod depending from the end of the lever, during the operation of drawing and charging, and opened again when the retort lid is closed.

It is well known that the gas as it ascends to the hydraulic main, after being in contact with the intensely heated surface of the retorts in which it is generated from the coal, is of a comparatively low temperature. The reason of this is not apparent at a cursory glance.

At first sight it would appear as though the action upon the gas in a retort would be similar to the effect upon air by the ovens of blast furnaces, where a million cubic feet are heated in the space of an hour to 633° Fahr., the melting point of lead. So far from this being the case, the permanent gas at its highest temperature does not probably exceed 135° Fahr., though generated in a heat usually reaching 2200°. The reason of the difference in the effect produced in the two instances given, is explained by the fact of the rapid absorption of heat by the volatile constituents of the coal in assuming the gaseous form; this heat becoming latent in the gas, as in the case of the formation of steam in an open boiler.

The following is a record of experiments made by the writer to determine the temperature of the gas as it issues from the retort :—

Experiment No. 1.

This experiment was conducted entirely under the usual conditions of working.

Clay retort, 20 feet through, one in a setting of seven.

Heat, bright cherry red.

Hole drilled in both ascension-pipes 3 feet above the mouthpiece.

Retort charged with 4 cwt. of cannel.

Temperature indicated on insertion of thermometer through the hole on one side of bench, 193° Fahr.

Temperature indicated on insertion of thermometer through the hole on the other side, 510° Fahr.

The temperatures indicated were clearly not those of the gas. In attaining the higher temperature, especially, the mercury rose by starts at the rate of 3° to 5° at once, evidently caused by hot particles of solid carbon, or other solid or semi-fluid substances, coming suddenly in contact with the bulb of the thermometer.

The remarkable difference in the temperature of the two sides is accounted for in this way. On the side in which 193° was indicated the dip-pipe was probably sealed to a greater depth in the hydraulic main, and consequently the flow of gas was neither as abundant nor as rapid on that side as on the other. This was evidenced by the thermometer on withdrawal being found less thickly coated with tar than in the other case. The gas was in a more quiescent state, and therefore there was not the same rush of hot solid particles against the bulb to raise the temperature abnormally.

It may be noted incidentally here, that indications of temperature thus obtained would prove whether the ascension-pipes at the two ends of a through retort were each taking their due share of the gas being produced.

Experiment No. 2.

The conditions were the same as in the previous instance; but instead of inserting the thermometer directly through the hole in the ascension-pipe, the end of a piece of india-rubber tube, 12 inches long, $\frac{3}{4}$-inch bore, was pressed against the orifice, and the gas allowed to flow in a stream through the tube. The object of employing the tube was to obviate, if possible, the contact of the semi-solid or semi-fluid substances previously referred to.

The result was: Temperature indicated on one side 250°, ditto on the other side 324°.

The rise of the mercury was still somewhat irregular, and the instrument, so much as was inserted, was again thickly coated with tar.

Experiment No. 3.

One end of the through retort was now bricked up, being made perfectly gas-tight, the gas passing away by one only of the

ascension-pipes; in point of fact, the retort was made single instead of through.

In a short double-flanged piece of the ascension-pipes, within 8 inches of the top of the mouthpiece, were inserted six layers of iron wire netting, cut into discs, accurately fitting the bore of the pipe. Three of these discs had meshes one-eighth, and the other three three-sixteenths of an inch gauge; and the discs were kept three-fourths of an inch apart by sheet-iron rings, inserted edgeways into the pipe.

The charge, 2 cwt. of cannel, thrown into the retort, happened to be taken from a heap that had been exposed to the rain, and there was considerable moisture present.

The hole through which the thermometer was inserted, as in the previous experiments, was 8 feet above the mouthpiece.

The following were the temperatures indicated:—

Time. Minutes.	Temp. Fahr. Degrees.	Time. Minutes.	Temp. Fahr. Degrees.
10	200	55	177
15	198	60	174
20	195	65	172
25	192	90	160
30	190	105	158
35	188	120	150
40	184	130	150
45	182	140	148
50	179	150	142

Through all the higher temperatures, down to 172°, steam was condensed into drops upon a piece of paper held in the stream of gas issuing from the hole. Tar, though not entirely absent, was nearly so, the instrument on each withdrawal being but slightly coated. The temperature, with but few exceptions, rose with great regularity from that of the atmosphere of the retort house (74°) to the rates observed, showing that the semi-solid particles, which were evidently the cause of the high temperatures previously indicated, had been nearly all arrested by the wire netting.

The higher temperatures, I am of opinion, were due to the presence of steam in the gas in varying proportions, and this latter would be caused by the moisture in the coal.

Experiment No. 4.

The retort was again charged, this time with 2 cwt. of cannel in a drier state. All the other conditions were as in the previous trial. The following were the results obtained:—

Time. Minutes.	Temp. Fahr. Degrees.	Time. Hours.	Temp. Fahr. Degrees.
2	158	1¾	129
7	174	2	123
12	177	2¼	122
17	172	2½	119
22	171	2¾	118
27	169	3	116
32	168	3¼	113
75	141	3½	110
90	134		

During the first half-hour of the charge, the presence of steam, mixed with the issuing gas, was indicated as before, but less abundantly, though still, doubtless, affecting the results obtained. When the temperature of the gas within 3 feet of the mouthpiece was at 174°, it stood at 132° in the bridge-pipe, 14 feet higher up.

Temperature of the Gas in the Bridge-Pipe, 14 *feet from the Retort Mouthpiece.*

Experiment.	2-cwt. Charges.	Temp. of the Gas.
No. 1	retort charged 1 hour	135° Fahr.
„ 2	„ „ 3 hours	116° „
„ 3	„ „ 4½ hours	119° „

It may be suggested that the effect of passing the gas through the wire netting would be to lower the temperature of the gas, just as the wire gauze on a Davy lamp reduces the temperature of the flame impinging against it. The conditions of the two cases, however, are entirely different. The meshes were sufficiently large to admit of an easy passage for the gas, and the metal would be immediately covered with a thick coating of tar, virtually producing insulation. In addition to that, the temperature within 6 inches of the front of the bench was 208°; and the metal of the ascension-pipe, as well as the inserted wire netting, would, as a rule, be above the temperature of the gas.

The results of these researches will be found to confirm, in a remarkable manner, the deductions of earlier investigators.*

* Mr. J. T. Sheard differs from the conclusions attempted to be drawn from the experiments recounted above, and his opinion carries weight with the writer. In a communication, he says:—

Coal must be raised to 600° F. before any volatile matters whatever are given off, and so-called permanent gases are not formed until a temperature of about 1100° F. is attained. Without being able to dogmatize, it is safe to assume that heavy hydrocarbons—volatile at the temperature of the retort, but liquid, or even solid, at atmospheric temperatures—are first formed; which, with more heat, are gradually broken up into lighter compounds of less complex composition, permanent simple gases being the ultimate products. With the first class of substances the action is similar in effect to the melting of ice into water, and its conversion into steam when sufficient heat is applied. A great portion of the total heat supplied becomes latent in the steam; *but the steam is evolved at the boiling temperature, 212° F. at least;* that is, it has itself acquired the temperature at which it was formed. So the hydrocarbon vapours formed at 600° F. or 1000° F., must, at the instant of liberation, be themselves of the temperature at which they were evolved from the coal or semi-liquid intermediate product from which they were formed.

Your contention, I take it, however, is that the permanent gases are in a different category because of their greater latent heat, and the fact that they are naturally gaseous at a much lower temperature than that at which they are formed in the retort. It seems impossible to put the matter directly to the test, but I cannot conceive how a particle of gas, formed, say, within a mass of hydrocarbon vapour, can be liberated at a temperature much lower than that of the atmosphere in which it is created. In default of proving the point in a direct manner, I have tested it indirectly by inquiring whether, assuming the gas to be liberated at the higher temperature, the known laws of cooling are sufficient to account for the great loss of heat which you observed immediately after the gas had left the hot retort.

The temperature of the gas in the ascension-pipe, 3 feet from the mouthpiece, was found to be 174° F., while in the bridge-pipe, 14 feet higher up, it was 132° F.

I assume that the retort was yielding gas at the rate of 6,000 cubic feet per day, or say 9 lbs. of gas and 9 lbs. of tar and liquor = 18 lbs. total weight of gases and vapours evolved per hour. I take the specific heat of the gas at 2·2, and of tar and liquor vapours at 0·6, or a mean of 1·6. Assuming the temperature of the gas as it leaves the retort to be 1000° F.,† while at 3 feet above the mouthpiece it was found to be only 174° F., then the heat dissipated between those points in one hour is as follows:—

$$18 \text{ lbs.} \times 1{\cdot}6 \text{ sp. heat} \times (1000° - 174°) = 23{,}790 \text{ units.}$$

The temperature of the air surrounding the pipe I take at 208° F. Probably it would be much lower, as that was the temperature found within 6 inches of the front of the setting. Therefore the difference to be dissipated is—

$$\text{Mean temperature of gas to be cooled, } \frac{1000+174}{2} = 587° - 208° = 379° \text{ F.}$$

By Webber's formula (*Journal of Gas Lighting*, Vol. 32, p. 14), the heat lost by radiation and contact is—

$$[\cdot 7583 \times 379 \times 6{\cdot}5] + \left[\left(\cdot 421 + \frac{\cdot 307}{5}\right) + 379 + 2\right] = 2250$$

units of heat per square foot of exposed surface per hour. Total heat actually lost as above, 23,790 units. Calculated surface required $= \frac{23790}{2250} = 10\frac{1}{2}$ square feet. In the mouthpiece 21″ × 15″ × 15″ there is, say, $6\frac{1}{2}$ square feet. In 3 ft. of 6-in. pipe there is $4\frac{1}{2}$ square feet. Total, 11 square feet, or more than sufficient cooling surface to produce the observed result.

Calculating in a similar manner for the difference between the temperature at 3 feet from mouthpiece 174,° and that in the bridge-pipe 132° F., I find there is similar accord between theory and practice, calculation and observation, which appears to give further ground for accepting the assumption started with as a correct one.

† The temperature within the mass of coal, 3 feet from the mouthpiece and one hour after charging, has been found to be about 1150° F.

Retort House Tools and Appliances.—For charging retorts by hand, the shovel or the scoop is used.

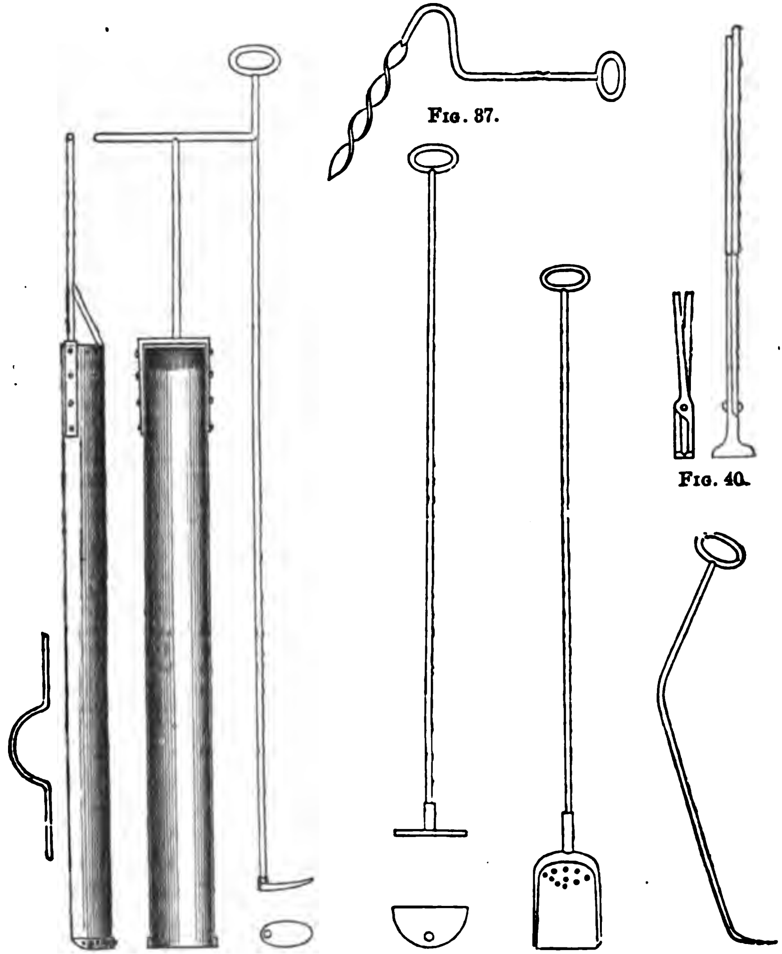


FIG. 37. FIG. 40.

FIG. 35. FIG. 36. FIG. 38. FIG. 39. FIG. 41.

Shovels with riveted handles are not good in or about a retort house. The heat soon causes the wood to dry in, and the rivets give way and become jagged, lacerating the hands of the men who use them. Socketed handles are the best.

A good handy-sized shovel for charging retorts of the ordinary size is one 16 inches long by 11 inches wide. Firing shovels (for coke) are best made an inch wider. Both should be well turned up at the sides.

The scoop (Fig. 35) is a semi-circular trough of sheet-iron or steel, the length of half the through retort, and of capacity to contain about 1¼ or 1½ cwt. of coal. It is inserted twice into the retort at each end. Six men are required to charge a through retort with the scoop—*i.e.*, three at each mouthpiece. The method of using it is as follows:—On its being filled with coal one man takes hold of the handle at the end, raises it slightly, the "horse" (as it is called) is placed underneath by a second man, and a third grasps the opposite side. The three then raise the scoop and insert its end into the retort mouth, whereupon the "horse" is released, and the man having hold of the handle pushes the scoop with its charge right into the retort, turns it round, and withdraws it, leaving the charge inside. This operation is repeated a second time; the scoop on the first insertion being turned to the left, and on the second to the right.

Other retort house tools consist of the discharging rake (Fig. 36); auger (Fig. 37); ash-pan rake (Fig. 38); and shovel (Fig. 39); fire tongs (Fig. 40); and pricker (Fig. 41); and coal and coke barrows.

Machine Charging and Drawing.—The difficult problem of applying machinery to the charging and drawing of retorts is one which has occupied the minds of gas engineers from the very introduction of gas-lighting, and its solution has been attempted with varying success. Out of about twenty different contrivances that have been invented for the purpose, not more than three or four remain in use at the present time, and these only to a limited extent. It has been solved most successfully by Mr. William Foulis and Mr. John West respectively, in their well-known ingenious labour-saving machines now extensively used for that purpose.

Clegg attempted to perfect an arrangement by which a continuous supply and discharge was effected; and though he did not succeed in producing an economical and satisfactory apparatus, it is greatly to be desired that other efforts in the same direction may be crowned with success.

CONDENSATION.

The cooling or condensing of the crude gas is an indispensable preliminary to its purification. Although the heavier tars are deposited in the hydraulic and foul mains within the retort house, there are lighter tars which continue suspended in the gas in the form of vapour, and are carried forward until a reduction in the temperature causes their deposition.

Although it is commonly said that "thorough condensation is half the purification," the degree of condensation to which coal gas should be subjected after leaving the retorts, and before entering the purifiers, has never been determined with that scientific accuracy which the importance of the subject demands.

With respect to one point there cannot be two opinions—viz., the necessity of guarding against a lower temperature in the gas than 50° Fahr. If condensation is carried beyond this, the lighter hydrocarbons are in danger of being deposited, and the gas impoverished.

The bad effects of excessive refrigeration are shown in the following table, which exhibits the loss of illuminating property in coal gas on exposure to the temperature of freezing point, 32° Fahr.:—

Name of Gas.	Hydrocarbons condensed from 1000 Cubic Feet of Gas on Exposure to a Cold of 32° Fahr.
Boghead cannel	4·42 cubic feet.
Ince Hall ditto	·37 ,,
Methyl ditto	·33 ,,

From which it appears that the richest gas suffers the greatest deterioration on being subjected to cold.

Experience has sufficiently proved that rapid or sudden, as well as excessive, condensation is an evil to be avoided; and that to prevent the deposition of naphthalene in the pipes, and preserve some of the richer illuminants, the gas should be allowed to travel in contact with the lighter tars until the latter are reduced in temperature to about 100° Fahr. before separation takes place.

With this object in view, the pipe leading from the hydraulic main may be carried with a gradual inclination round the interior of the retort house or other convenient building, and from thence to the condenser; provision, of course, being made to allow the thicker tar to run off at a point near to the hydraulic main. By this arrangement

the gas is slowly reduced in temperature, and some of its most valuable light-giving hydrocarbons, which would otherwise be condensed, are retained within it in the permanent state.

Naphthalene.—In dealing with the subject of condensation, that of the formation or deposition of naphthalene may be appropriately discussed. This hydrocarbon when deposited in the solid state in the apparatus and mains of a gas-works, and in the distributing pipes in the streets, is exceedingly troublesome; sometimes entirely blocking the passage of the gas, and entailing much labour and expense in its removal.

It is generally believed that the presence of naphthalene in gas is due, principally, to the high heats necessarily used in the carbonization of the coal, owing to the partial distillation of a portion of the tar. In the early days of gas-lighting, when iron retorts were used exclusively, and the heats were comparatively low, naphthalene as now found in the mains in the solid state was almost unknown. It was not until clay retorts came to be employed, and the heat of carbonization was increased, that naphthalene made its appearance.

It is well known by its flaky crystalline structure, and its peculiar ethereal odour. It is not soluble in water, but easily so in naphtha; hence its removal is effected by steaming with naphtha vapour, or by pouring that liquid into the obstructed mains and apparatus.

Naphthalene is deposited most freely from gas produced from bituminous coal. Some kinds of coal yield it in greater abundance than others. By using a proportion of cannel along with the coal, the gas, being enriched, is enabled to retain some or the whole of the naphthalene in suspension within it in the gaseous condition. The richer the gas, the more capable it is (under ordinary conditions) of retaining the constituents which contribute to its enrichment and *vice versâ*.

In the year 1877 M. Brémond published an account of a series of valuable researches made by him on the question of the formation of naphthalene and its deposition, in which he showed that (to use his own words) "naphthalene is produced wherever there is condensation of the aqueous vapours contained in the gas; that its deposition is preceded by the phenomenon of the condensation of the water; and that gas absolutely deprived, as far as possible, of aqueous vapour does not deposit naphthalene under the ordinary conditions of temperature and pressure."

It is clear, therefore, that the subject of condensation is one of the utmost importance, if naphthalene, or an excess of it, is to be got rid

of. But however perfect the ordinary condensing apparatus may be, it is almost impossible to deprive gas of its aqueous vapour by this means. M. Brémond therefore adopted other means of drying the gas; and for this purpose he employed an ordinary lime purifier, but instead of filling it with slaked or hydrated lime, he charged it with unslaked lime in lumps. By passing the gas through this unslaked lime he completely desiccated the gas, with the interesting result that the aqueous vapour, and consequently the excess of naphthalene also, was arrested. The gas thus deprived of its moisture was found to have increased in illuminating power to a considerable extent.

This remarkable result of drying the gas had previously been observed by the first London Gas Referees. They found that the gas made at Beckton actually gained in illuminating power in traversing the long length of mains from Beckton to London; and they remark as follows: "In considering the satisfactory result of the novel and somewhat perilous enterprise, the Referees are inclined to account for it [the increase in the illuminating power] mainly by the slow and gradual withdrawal of aqueous vapour from the gas in its long journey. This condensation is very different in character from the sudden withdrawal of aqueous vapour produced by the application of great cold, for it takes place very gradually, so that the water is deposited without any appreciable portion of the hydrocarbons being condensed along with it. In order to ascertain the effect of withdrawing the aqueous vapour from gas, we made several experiments by passing the gas through porous chloride of calcium; the results showing that dry gas has a superiority in illuminating power over ordinary gas to the extent of from 6 to 8 per cent.

The experiments of M. Brémond are recounted to show the philosophy underlying the facts, rather than for the purpose of recommending his remedy, which would be cumbrous in practice.

Various other remedies adopted have proved more or less successful. Mr. Botley accomplishes the retention of naphthalene by carburetting the gas after the holders with petroleum oil in the form of mist, produced mechanically. Another method, which has proved efficient, is to vaporise carburine by means of steam, mixing it in the proportion of about twelve gallons of the oil per million cubic feet of gas passing into the holders. These processes are on the lines indicated in the foregoing arguments dealing with the condensable and other hydrocarbons.

The remedy for the objectionable deposit of naphthalene is thus in the gas maker's own hands to a great extent.

The make of gas, as indicated by the station-meter, is materially affected by the temperature at which it is registered.

At the temperature of 60° Fahr., with the barometer at 30 inches, gas is at its standard volume; and as all aëriform bodies expand $\frac{1}{491\cdot2}$ of their bulk at 32° Fahr. for every additional degree of temperature, or about 1 per cent. for 5°, it follows that a quantity of gas, say 10,000 cubic feet registered at 60°, would at 70° become 10,203·5, and at 80° 10,407.

The quantity of heat which will raise a cubic foot of water one degree, will raise 2,850 cubic feet of gas or atmospheric air to the same extent.

TABLE.—EXPANSION OF AIR AND PERMANENT GASES BY HEAT.

Temp. Fahr. Degrees.	Expansion.	Temp. Fahr. Degrees.	Expansion.	Temp. Fahr. Degrees.	Expansion.	Temp. Fahr. Degrees.	Expansion.
32	1000	52	1040·700	72	1081·400	92	1122·100
33	1002·035	53	1042·735	73	1083·435	93	1124·135
34	1004·070	54	1044·770	74	1085·470	94	1126·170
35	1006·105	55	1046·805	75	1087·505	95	1128·205
36	1008·140	56	1048·840	76	1089·540	96	1130·240
37	1010·175	57	1050·875	77	1091·575	97	1132·275
38	1012·210	58	1052·910	78	1093·610	98	1134·310
39	1014·245	59	1054·945	79	1095·645	99	1136·345
40	1016·280	60	1056·980	80	1097·680	100	1138·380
41	1018·315	61	1059·015	81	1099·715	110	1158·730
42	1020·350	62	1061·050	82	1101·750	120	1179·080
43	1022·385	63	1063·085	83	1103·785	130	1199·430
44	1024·420	64	1065·120	84	1105·820	140	1219·780
45	1026·455	65	1067·155	85	1107·855	150	1240·130
46	1028·490	66	1069·190	86	1109·890	160	1260·480
47	1030·525	67	1071·225	87	1111·925	170	1280·830
48	1032·560	68	1073·260	88	1113·960	180	1301·180
49	1034·595	69	1075·295	89	1115·995	190	1321·530
50	1036·630	70	1077·330	90	1118·030	200	1341·880
51	1038·665	71	1079·365	91	1120·065	212	1366·300

In instituting a comparison between the production per ton of material at different works, and in testing the productive value of different coals, it is, therefore, necessary to take into account the temperature of the gas at the time of measurement. In ascertaining the specific gravity of gas, and in conducting photometrical observations, the same care should be taken to note the temperature at the time and place of making the experiment.

TABLE.—Giving the Mean Temperature (Fahr.) of every Tenth Day in the Year in the Central District of England. (Box.)

Month.	1st.	11th.	21st.	Month.	1st.	11th.	21st.
	Deg.	Deg.	Deg.		Deg.	Deg.	Deg.
January	36·5	35·6	37·1	July	61·2	61·5	62·0
February. . . .	37·2	37·5	38·5	August	62·5	61·7	60·6
March	40·1	41·0	41·9	September . . .	58·8	57·4	55·5
April	43·6	45·0	47·0	October	53·5	51·4	49·0
May	50·0	51·3	53·8	November . . .	46·4	44·0	42·0
June	56·4	57·5	59·8	December . . .	41·7	40·2	38·4

Condensers.—The Atmospherical Horizontal Condenser (Fig. 42) is one of the earliest forms of the apparatus. Its efficiency has not

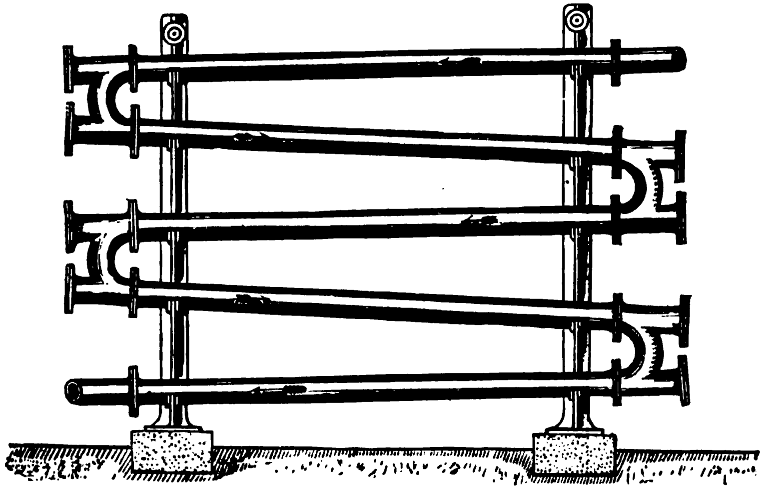


Fig. 42.

been generally recognized, owing to the want of a correct appreciation of the conditions on which the condensation of coal gas ought to be conducted, and this has led to its being generally discarded in favour of the vertical form.

The earlier method of construction was to fix it against the outside of the wall of the retort house or other convenient building; the several pipes rising with a slight inclination one above the other to allow of the flow of the condensed products, their ends being connected by ⊃-shaped bends.

Graham's condenser (Fig. 48) is an improvement on this. It consists of a series of pipes arranged in pairs side by side, and supported on framework, the end of each length being joined to that of the next. From the inlet at the top, through the entire run of the condenser to the outlet at the bottom, there is a gradual inclination, so that it is simply a flat screw or spiral, such as might be represented

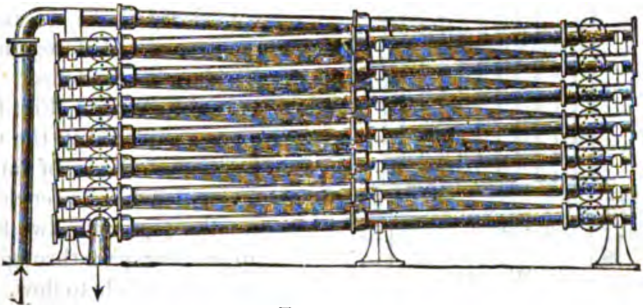


FIG. 43.

by winding a length of soft wire round a piece of board, in which case the two ends of the wire would answer to the inlet and outlet of the condenser. Blank flanges are bolted on the end of each length for convenience in cleansing.

In this arrangement there is a recognition of the fact that *length* rather than *height* is the desideratum in an atmospherical condenser. In the ordinary vertical form of the apparatus, the cooling effect of the air on the surface of the upper parts of the pipes is almost *nil*. This will be obvious when it is considered that the air contiguous to the lower part of the condenser, being assimilated to the temperature of the latter, expands, and so, becoming lighter than the surrounding air, ascends in contact with the pipes, extracting less heat in proportion as it rises.

In addition to the other advantages, the ammoniacal liquor on leaving the horizontal condenser is of a strength equal to 5° Twaddel—a result which it is impossible to obtain from the ordinary vertical form.

The ordinary atmospherical condenser (Fig. 44) consists of a series of pipes, usually 18 feet long, put together in two lengths, and placed upright, through which the gas passes up and down alternately. These enter a rectangular cistern at bottom, in which the condensed vapours are deposited, and from whence they flow to the tar well. At the

top is another cistern, containing water to seal the movable hoods covering each pair of pipes, and for further refrigeration, should such be required, in warm or sunny weather, small streams being made to trickle down the exterior surface of the pipes.

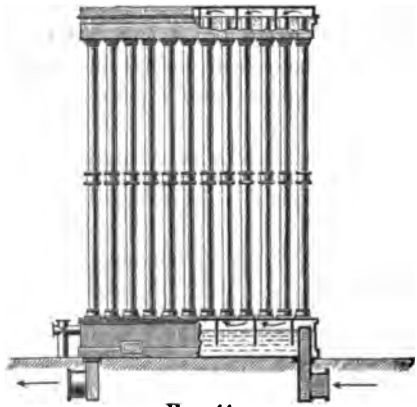


Fig. 44.

The annular condenser is considered to be an improvement on the foregoing. In Kirkham's condenser, as improved by Wright (Fig. 45), the pipes are placed in the vertical position, and are of large diameter, each one enclosing a smaller pipe; the two forming an annular space through which the gas is made to flow. Other pipes, placed diagonally, connect the top and bottom of the condensing columns alternately. By this arrangement the gas passes through the annular space always in the downward direction, whilst the current of air moves upward through the interior ventilating pipe. In cold weather movable covers are placed over the latter, or butterfly valves are fixed at the foot, for closing, to regulate the air draught, which might otherwise reduce the temperature of the gas below the desired standard. A small pipe is connected to the bottom of each column to carry away the deposited tar and water into a main laid alongside the condenser, and leading into the tar well.

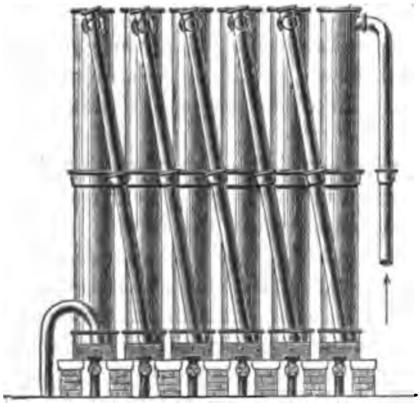


Fig. 45.

Instead of the diagonal pipe, extending from the top to the bottom of each column alternately, Mr. Warner has inserted a mid-feather or partition, within the annular chamber. This reaches to within a short distance of the top and bottom, the space at the lower end being

sealed by the deposited fluids, and a short connecting piece joins the several columns at the base. By this modification, a free passage is obtained from end to end for the condensed fluids, and the separate tar main is dispensed with.

Cleland's slow-speed condenser consists of a series of vertical pipes, connected together at the top by a tubular cornice or cap, which serves as the common inlet to the whole series. The stream of gas being thus divided equally amongst the several columns, travels through them in a downward direction and at a comparatively slow speed.

In the lower part of each column, to about a fifth part of its length, is inserted a "bottle brush" of wood or other material, with a drip-ledge above it to divert the descending liquor on to the centre of the brush, which has the effect of converting the apparatus, to that extent, into a scrubber.

The general result is superior efficiency in condensing, and the yield of a high strength of liquor.

An excellent apparatus (atmospherical) is that known as the battery condenser (Fig. 46). This is an oblong vessel, 12 to 24 inches wide,

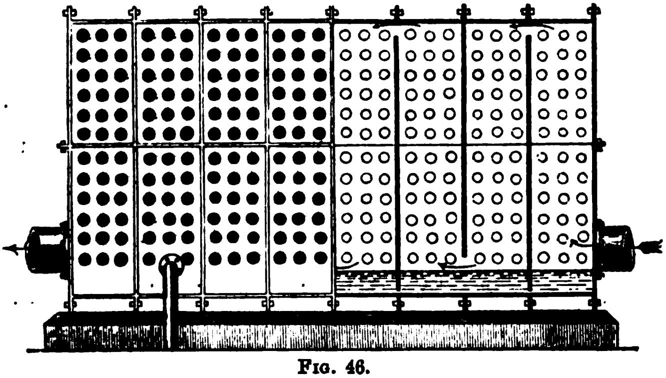


Fig. 46.

12 to 18 feet in height, and of length suitable to the requirements of the works. It is divided by internal plates or mid-feathers, placed at distances, equal to the width, apart, extending to within a few inches of the top and bottom of the chest alternately; and the gas passes from the inlet, up and down each division, till it arrives at the outlet. To augment its condensing power, small tubes, 2 inches in diameter, through which the air has free circulation, are passed through from side to side of the vessel, and there securely jointed. These trans-

verse tubes serve the double purpose of cooling the gas, and, by breaking it up and retarding its progress, inducing a natural settlement of the heavy condensable vapours.

It may be taken as a general rule that about 10 superficial feet of atmospherical condensing surface for each 1000 cubic feet maximum gas production per day of 24 hours, should be provided. This is assumed to include the length of foul main extending from the hydraulic main. Moreover, the condenser should be protected from the direct action of the sun's rays, or otherwise water should be made to trickle down the outer surface of the pipes during sunshine.

Mr. Livesey, in some of his condensing arrangements, adopts the plan of placing the condensing pipes in a tank divided into channels, through which a stream of water is made to flow, and which can be regulated according to the make of gas. The water enters the tank at the point where the condensed gas makes its exit, and, flowing in the opposite direction to the gas in the pipes, is gradually raised in temperature by the latter till it reaches its outlet, where the crude gas enters. By this means a more uniform condensation is obtained than is possible in the atmosphere.

In this connection the following table by Peclet, showing the relative effects of water and air as cooling agents, is interesting and useful:—

Excess of Temperature in the Gas over the Atmosphere.	Quantity of Heat lost by a Square Unit of Exterior Pipe Surface. When Radiating in Air.	When plunged in Water.
For an excess of 10°	8	88
" " 20°	18	266
" " 30°	29	5,353
" " 40°	40	8,944
" " 50°	53	13,437

Water is thus shown to be the superior cooling agent, requiring the exposure of much less radiating surface than air; but, for the reasons already adduced, the temperature of the water must be regulated in order to avoid any sudden condensation.

An apparatus that is being rather widely adopted is the combined atmospherical and water condenser. This is made in different forms, the principle of each being the same. It is constructed either of ordinary pipes having small tubes passing through their interior, or of cylindrical or square chambers filled with such tubes, and placed either horizontally or vertically, the latter by preference. Through the tubes a stream of water is made to flow in the opposite direction to

that of the gas which surrounds them, so that by the time the water reaches the inlet of the condenser, it has, by absorbing the heat of the gas, attained a comparatively high temperature, and thus any sudden cooling of the gas at the entrance is avoided. The ease with which the cooling power of the apparatus can be varied and controlled, by increasing or diminishing the flow of the water, is a strong recommendation in its favour.

The underground condenser is so-called because the pipes are placed in the ground out of reach of the fluctuations of temperature in the atmosphere, with a view to obtaining uniformity of action in the process of condensation. By this system, however, a much longer length of piping is required than by any other, owing to the small amount of radiation from the surface of the buried pipes.

There is an advantage in this process of gradual condensation ; but it is advisable, wherever in use, to supplement it by finally passing the gas through one of the other forms of condensers having less than the usual area.

In some works condensation is effected by means of dry scrubbers —cast-iron vessels of large diameter—charged with coke, drain tiles, or other material, breaking up the gas into minute streams, which, being thus cooled, deposits its tar and water.

A natural settlement of the condensable matter also takes place, irrespective of the action of the contained material, owing to the velocity of the flow of the gas being reduced on entering the larger area.

The rapid fouling of these vessels, however, necessitating frequent changing of the filling material to prevent undue back pressure and maintain their efficiency, renders their use objectionable.

Precipitating chambers of large size are also employed, without any filling material, in which the gas sleeps, as it were, and deposits its condensable particles. A vessel of this kind is useful in other respects, because the large volume of gas serves as a cushion to counteract pulsatory action between the exhauster and the retorts.

The principle of Pelouze and Audouin's condenser is different to that of any of the other apparatus described. In construction it consists of an outer cylindrical cast-iron chamber, with the usual inlet for gas, and outlets for gas and liquids, and contains a cylinder of perforated sheet-iron constituting the condenser. The sides of the condensing chamber are two thin sheets of iron with a concentric space between. The inner sheet is perforated with holes 1-20th of an

inch in diameter, and the outer with slots of large size; the outer sheet being so arranged as to offer a blank surface opposite the small holes in the inner sheet. The gas and condensable vapours pass through the small perforations, the vapours being as it were wire-drawn, and striking against the opposite solid surface are deposited thereon, and flow down into the receptacle below, and thence to the tar well.

The gas passes on through the slots in the outer cylinder to the outlet pipe.

The condensing cylinder is so balanced as to rise and fall in an annular space containing tar or liquor which acts as a seal. As the make of gas increases or decreases, the cylinder rises or falls, and consequently a larger or less number of openings are uncovered for the passage of the gas. The result is a more complete separation of the tar from the gas than is attainable by any other form of condenser.

It has been attempted, though with doubtful success, to condense and carburet the gas at one and the same time. The Aitken and Young analyzer, and the St. John and Rockwell apparatus, were each designed by their inventors to enrich the gas by carburation. The tar and gas were both conveyed direct from the hydraulic main to the apparatus; their temperature at the inlet being maintained as high as possible. Means were even adopted of raising the temperature, if required, in order that the heavier hydrocarbons present in the crude gas and tar might be permanently suspended, and so become fixed illuminants in the gas, notwithstanding the subsequent reduction of

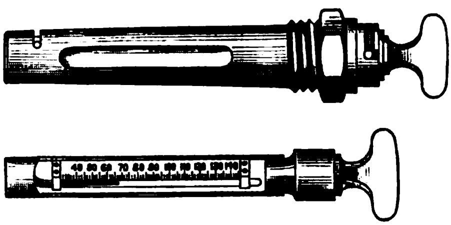


FIG. 47.

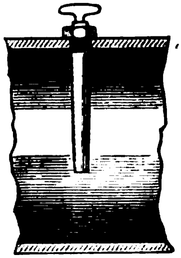


FIG. 48.

temperature in the ordinary course of purification. Great hopes of the process were at one time entertained, but it failed to meet the expectations of the inventors.

Drory's Main Thermometer.—The illustrations, Figs. 47 and 48, show the improved arrangement invented by Mr. Drory, for ascertaining

the temperature of the gas passing through the condenser and other apparatus, and the mains. It consists of an outer shell fitted with a conical hollow plug having an aperture corresponding to that in the outer shell. The tester which fits into the plug contains a thermometer, which on being turned opposite to the apertures is in immediate contact with the gas, and on withdrawal the temperature is ascertained. For attaching the tester, a hole suitable for a 1-inch wrought-iron pipe is drilled and tapped in the pipe or side of the apparatus, and the instrument is screwed therein.

To convert Degrees of Fahrenheit into those of Centigrade and Réaumur, and conversely.

To convert Fahr. into Cent.

RULE 1st.—Subtract 32, and divide the remainder by 1·8, thus:

$$\text{Fahr. } \frac{167 - 32}{1{\cdot}8} = 75 \text{ Cent.}$$

or by—

RULE 2nd.—Subtract 32, multiply the remainder by 5, and divide the product by 9, thus:—

$$\text{Fahr. } \frac{(167 - 32) \times 5}{9} = 75 \text{ Cent.}$$

To convert Cent. into Fahr.

RULE 1st.—Multiply by 1·8, and add 32, thus:—

$$\text{Cent. } 75 \times 1{\cdot}8 + 32 = 167 \text{ Fahr.}$$

or by—

RULE 2nd.—Multiply by 9, divide by 5, and add 32, thus:—

$$\text{Cent. } \frac{75 \times 9}{5} + 32 = 167 \text{ Fahr.}$$

To convert Fahr. into Réau.

RULE 1st.—Subtract 32, and divide by 2·25, thus:—

$$\text{Fahr. } \frac{113 - 32}{2{\cdot}25} = 36 \text{ Réau.}$$

or by—

RULE 2nd.—Subtract 32, multiply by 4, and divide by 9, thus:—

$$\text{Fahr. } \frac{(113 - 32) \times 4}{9} = 36 \text{ Réau.}$$

To convert Réau. into Fahr.

RULE 1st.—Multiply by 2·25, and add 32, thus:—

$$\text{Réau. } 36 \times 2{\cdot}25 + 32 = 113 \text{ Fahr.}$$

or by—

RULE 2nd.—Multiply by 9, divide by 4, and add 32, thus:—

$$\text{Réau. } \frac{36 \times 9}{4} + 32 = 113 \text{ Fahr.}$$

In connection with the subject of Condensation, the following Table, comparing the English and French Thermometers, will be found useful :—

Fahr.	Réau.	Cent.	Fahr.	Réau.	Cent.	Fahr.	Réau.	Cent.	Fahr.	Réau.	Cent.
212	80·0	100·0	160	56·8	71·1	108	33·7	42·2	56	10·6	13·3
211	79·5	99·4	159	56·4	70·5	107	33·3	41·6	55	10·2	12·7
210	79·1	98·8	158	56·0	70·0	106	32·8	41·1	54	9·7	12·2
209	78·6	98·3	157	55·5	69·4	105	32·4	40·5	53	9·3	11·6
208	78·2	97·7	156	55·1	68·8	104	32·0	40·0	52	8·8	11·1
207	77·7	97·2	155	54·6	68·3	103	31·5	39·4	51	8·4	10·5
206	77·3	96·6	154	54·2	67·7	102	31·1	38·8	50	8·0	10·0
205	76·8	96·1	153	53·7	67·2	101	30·6	38·3	49	7·5	9·4
204	76·4	95·5	152	53·3	66·6	100	30·2	37·7	48	7·1	8·8
203	76·0	95·0	151	52·8	66·1	99	29·7	37·2	47	6·6	8·3
202	75·5	94·4	150	52·4	65·5	98	29·3	36·6	46	6·2	7·7
201	75·1	93·8	149	52·0	65·0	97	28·8	36·1	45	5·7	7·2
200	74·6	93·3	148	51·5	64·4	96	28·4	35·5	44	5·3	6·6
199	74·2	92·7	147	51·1	63·8	95	28·0	35·0	43	4·8	6·1
198	73·7	92·2	146	50·6	63·3	94	27·5	34·4	42	4·4	5·5
197	73·3	91·6	145	50·2	62·7	93	27·1	33·8	41	4·0	5·0
196	72·8	91·1	144	49·7	62·2	92	26·6	33·3	40	3·5	4·4
195	72·4	90·5	143	49·3	61·6	91	26·2	32·7	39	3·1	3·8
194	72·0	90·0	142	48·8	61·1	90	25·7	32·2	38	2·6	3·3
193	71·5	89·4	141	48·4	60·5	89	25·3	31·6	37	2·2	2·7
192	71·1	88·8	140	48·0	60·0	88	24·8	31·1	36	1·7	2·2
191	70·6	88·3	139	47·5	59·4	87	24·4	30·5	35	1·3	1·6
190	70·2	87·7	138	47·1	58·8	86	24·0	30·0	34	0·8	1·1
189	69·7	87·2	137	46·6	58·3	85	23·5	29·4	33	0·4	0·5
188	69·3	86·6	136	46·2	57·7	84	23·1	28·8	32	0·0	0·0
187	68·8	86·1	135	45·7	57·2	83	22·6	28·3	31	— 0·4	— 0·5
186	68·4	85·5	134	45·3	56·6	82	22·2	27·7	30	— 0·8	— 1·1
185	68·0	85·0	133	44·8	56·1	81	21·7	27·2	29	— 1·3	— 1·6
184	67·5	84·4	132	44·4	55·5	80	21·3	26·6	28	— 1·7	— 2·2
183	67·1	83·8	131	44·0	55·0	79	20·8	26·4	27	— 2·2	— 2·7
182	66·6	83·3	130	43·5	54·4	78	20·4	25·5	26	— 2·6	— 3·3
181	66·2	82·7	129	43·1	53·8	77	20·0	25·0	25	— 3·1	— 3·8
180	65·7	82·2	128	42·6	53·3	76	19·5	24·4	24	— 3·5	— 4·4
179	65·3	81·6	127	42·2	52·7	75	19·1	23·8	23	— 4·0	— 5·0
178	64·8	81·1	126	41·7	52·2	74	18·6	23·3	22	— 4·4	— 5·5
177	64·4	80·5	125	41·3	51·6	73	18·2	22·7	21	— 4·8	— 6·1
176	64·0	80·0	124	40·8	51·1	72	17·7	22·2	20	— 5·3	— 6·6
175	63·5	79·4	123	40·4	50·5	71	17·3	21·6	19	— 5·7	— 7·2
174	63·1	78·8	122	40·0	50·0	70	16·8	21·1	18	— 6·2	— 7·7
173	62·6	78·3	121	39·5	49·4	69	16·4	20·5	17	— 6·6	— 8·3
172	62·2	77·7	120	39·1	48·8	68	16·0	20·0	16	— 7·1	— 8·8
171	61·7	77·2	119	38·6	48·3	67	15·5	19·4	15	— 7·5	— 9·4
170	61·3	76·6	118	38·2	47·7	66	15·1	18·8	14	— 8·0	—10·0
169	60·8	76·1	117	37·7	47·2	65	14·6	18·3	13	— 8·4	—10·5
168	60·4	75·5	116	37·3	46·6	64	14·2	17·7	12	— 8·8	—11·1
167	60·0	75·0	115	36·8	46·1	63	13·7	17·2	11	— 9·3	—11·6
166	59·5	74·4	114	36·4	45·5	62	13·3	16·6	10	— 9·7	—12·2
165	59·1	73·8	113	36·0	45·0	61	12·8	16·1	9	—10·2	—12·7
164	58·6	73·3	112	35·5	44·4	60	12·4	15·5	8	—10·6	—13·3
163	58·2	72·7	111	35·1	43·8	59	12·0	15·0	7	—11·1	—13·8
162	57·7	72·2	110	34·6	43·3	58	11·5	14·4	6	—11·5	—14·4
161	57·3	71.6	109	34·2	42·7	57	11·1	13·8	5	—12·0	—15·0

THE EXHAUSTER.

The exhauster is best placed to follow the condenser. The *raison d'être* of this apparatus, which is really nothing more nor less than a pump, is to relieve the retorts of the pressure caused by the obstruction offered to the gas in its passage through the washers, scrubbers, purifiers, and station meter into the holders.

Exhausters are now made of almost any size, down to the smallest, and there are but few gas-works, however small, where they cannot be applied with advantage. The invariable result of the use of the exhauster is to increase the production per ton, to improve the quality of the gas (provided air is not drawn in), and to lengthen the duration of the retorts, by preventing, in a great measure, the deposition of carbon, the removal of which with the ordinary chisel bars is so destructive and unsatisfactory.

Mechanical exhausters are of two kinds, the rotatory and the reciprocating. Both descriptions have their advocates, and much may be said in favour of each.

Beale's exhauster was the first one constructed on the rotatory principle. Its early form is shown in Fig. 49. Its parts consist of a cylinder, inside which a drum revolves, and is provided with pistons or slides which have a radial motion. The drum is smaller in diameter than the inside of the cylinder, and the centre lines or axes of both are parallel and horizontal; but the drum is placed eccentrically in the cylinder, so as to be in contact with it at the bottom without resting on it. The inlet and outlet passages are on the two opposite sides of the cylinder, and as the slides are guided by segments in the end plates, so that their outer ends are always in contact with the inside of the cylinder, the gas enters one side, is carried round over the drum to the other side, and is forced out at the outlet. This form of exhauster is the one now most generally adopted, and whilst the original type is retained, important modifications and improvements have been effected in its construction and action by

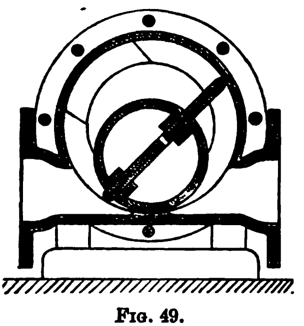


FIG. 49.

various makers of recent years—notably by Gwynne and Co., Bryan Donkin and Co., W. H. Allen and Co., and G. Waller and Co.

The illustrations (Fig. 50) show sections of a Beale's exhauster as made by Gwynne and Co. under their patents, and containing several improvements on the machine as first invented, by which the

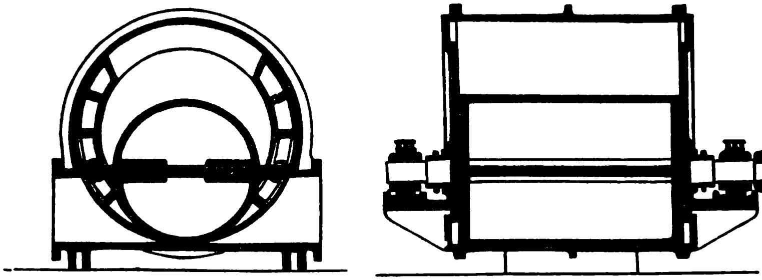


FIG. 50.

areas of wearing surfaces have been augmented so as to greatly increase the durability of the machine. These include the double slides, large segments, steel pins fastened in the segments and extending through the whole length of the slides, and the outside bearings for the axle.

In Fig. 51 is shown a section of Waller's three-blade exhauster, which the inventors consider to be an improvement on the two-bladed form of the apparatus. The delivery is divided into three parts instead of two, thus giving a steadier gauge. The exhauster can be run in either direction, using either branch pipe as the inlet or outlet, but the direction for running is always from the inlet. The blades turn on a centre spindle and are radial with the cylinder, which is a true circle. The same makers have produced a four-blade exhauster.

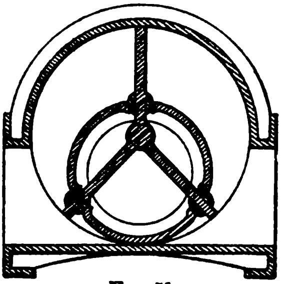


FIG. 51.

Anderson's exhauster, which may be taken as the type of the reciprocating form of the apparatus, is shown in Fig. 52. This works in the vertical position, but others, like Dempster's, have the engine and pumps placed horizontally.

The rotatory exhauster may be driven either by a strap from a line shaft actuated by a steam or gas engine, or by an engine coupled direct. The reciprocating exhauster is always driven directly by the engine.

By employing two of these latter exhausters, and working them from one engine, the slides of the exhausters being placed at right angles to each other, a perfectly steady vacuum and pressure are maintained.

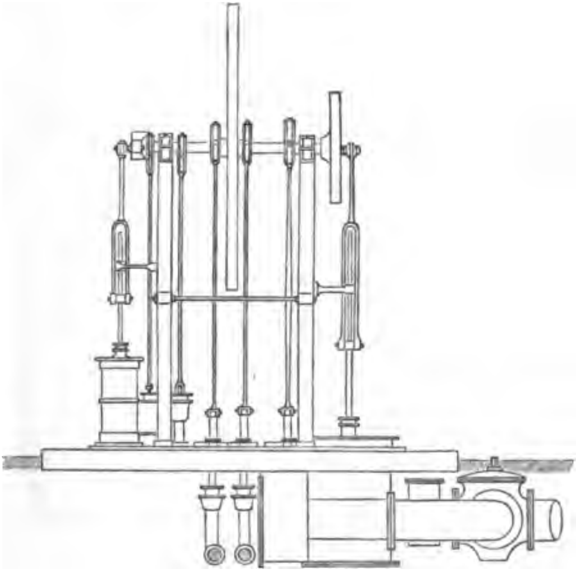


FIG. 52.

The essential features of a good exhauster are that it should be simple, and work with a minimum of friction and power, that it should give the steadiest possible flow of gas, and that the parts should be perfectly gas-tight. The commonest fault is want of tightness, and when it is remembered that, under a pressure equal to a 14-inch column of water, about 9000 cubic feet of gas will pass per hour through an opening of only one square inch in area, the absolute necessity of the best workmanship only being used in exhausters will be evident.

Crude creosote oil is the best lubricant for the cylinder and slides of an exhauster when the surfaces become "pitched" with tar.

The steam-jet exhauster (Fig. 53), invented by Mr. Cleland, and improved by Körting Brothers, is another form of exhausting apparatus. This operates by projecting a jet of steam, at about 45 lbs. pressure, through an arrangement of pipes or nozzles, without the intervention of any other mechanical appliances—the steam being afterwards extracted by condensation. The capacity of the exhauster is regulated by the adjustable screw and spindle at the end; and by a movable inner sleeve, opening or closing the port holes by means of the screw and nut at the side.

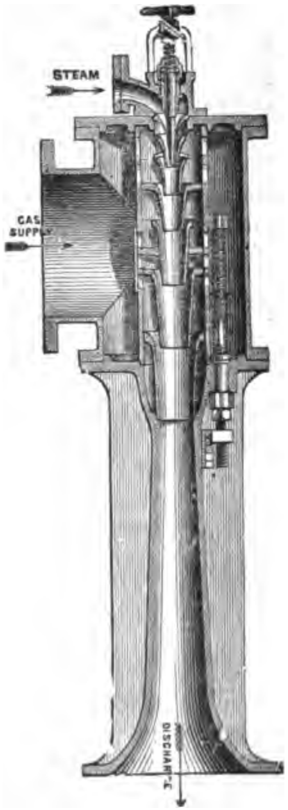


Fig. 53.

When an exhauster is employed, it is necessary to supplement its use by a gas governor, acting either on a throttle valve within the steam feed-pipe, in this case increasing or diminishing the speed of the engine, or on a valve within a bye-pass connected to the inlet and outlet mains leading to and from the exhauster, the opening of which, when the exhaust is too active, allows a portion of the gas to return through the exhauster, and thus prevents the formation of a partial vacuum in the retorts.

Steam Engines and Boilers.—These should be provided of ample size, allowing a margin over and above the actual power needed. An engine and boiler barely fit to do the work required of them are a nuisance.

The engine, besides turning the exhauster, may be used in pumping water and tar; and the boiler, in addition to supplying steam for the engine, is useful for steaming the mains and apparatus on the works.

Duplicate boilers of the required size should be provided, to allow for periodical cleaning and examination.

For firing the boiler, breeze may be used, mixed with a portion of coke or coal. Or if, instead of the chimney draught, a forced draught be employed, breeze and much of the furnace refuse will serve as fuel.

One pound weight of coal of average quality requires 150 cubic feet of air for its perfect combustion. In actual practice, however, about double this quantity of air passes through the furnaces of steam boilers.

Wherever practicable and convenient, the boiler may be set in such a position as to allow of its being heated with the waste heat from the retort-stack.

In small works, if a steam boiler cannot be employed for want of space, or should a boiler be considered objectionable on other grounds, the exhauster can be driven by a gas engine.

The boiler most suitable for a gas-works of moderate size is the Cornish type, with flat ends, and single internal tube containing the furnace. For large works, the Lancashire or double-flued boiler is best adapted.

The nominal horse power of a boiler is found by multiplying the sum of the diameters of the outer shell and internal flue by the length, and dividing the product by 6.

EXAMPLE.—Required the power of a Cornish boiler, whose diameter is 4 ft. 6 in., diameter of tube 2 ft. 6 in., and length 12 ft.

$$\frac{(4'\ 6'' + 2'\ 6'') \times 12'}{6} = 14\text{-horse power.}$$

Again—

Required the power of a Cornish boiler whose diameter is 6 ft., diameter of tube 3 ft., and length 20 ft.

$$\frac{(6' + 3') \times 20'}{6} = 30\text{-horse power.}$$

Again—

Required the power of a Lancashire boiler whose diameter is 7 ft., diameter of tubes 2 ft. 9 in., and length 24 ft.

$$\frac{(7'\ 0'' + 2'\ 9'' + 2'\ 9'') \times 24'}{6} = 50\text{-horse power.}$$

In high-pressure or non-condensing engines, with—

Steam at 25 lbs.	per square inch,	13·6	circular inches on piston	=	1-horse power.
Do.	30 lbs.	do.	11·3	do.	=	do.

The diameter of the piston in inches, squared = circular inches.

The following table gives the diameter of cylinders for high-pressure (non-condensing) steam engines, from 3 to 16 horse power,

with steam at 25 lbs. and 30 lbs. per square inch respectively, and the length of stroke for the different sizes :—

Nominal Horse Power.	Diameter of Cylinder in Inches. Steam per Square Inch. 25 lbs.	30 lbs.	Length of Stroke. Inches.	Nominal Horse Power.	Diameter of Cylinder in Inches. Steam per Square Inch. 25 lbs.	30 lbs.	Length of Stroke. Inches.
3	6½	6	12	8	10½	9½	20
3½	6¾	6¼	12	8½	10¾	9⅞	20
4	7¼	6¾	14	9	11⅛	10⅛	22
4½	7¾	7⅛	14	10	11¾	10¾	22
5	8¼	7½	16	11	12¼	11¼	24
5½	8½	7⅞	16	12	12¾	11⅝	24
6	9	8¼	18	13	13¼	12¼	26
6½	9½	8⅝	18	14	13¾	12¾	26
7	9¾	9	18	15	14⅛	13	28
7½	10⅛	9¼	20	16	15	13½	30

Cement for stopping leaks in boilers.

		By weight.
Powdered fire-clay	. . . . . .	6 parts.
Fine iron filings	. . . . . .	1 part.

Made into a paste with boiled linseed oil.

Cement for metallic joints.

Equal weights of red and white lead, mixed with boiled linseed oil to the consistency of putty.

THE WASHER.

The washer was one of the very earliest appliances used in the purification of coal gas, and naturally so, owing to the cooling and condensing property of water, and its power of absorbing ammonia and of arresting the tar. Its construction, however, was often faulty at first, and the limits of its functions misunderstood; so that the misuse, or overuse, of the apparatus, resulting in reduced illuminating power to the gas exposed to its action, caused it to fall for a time into disrepute.

The principle of its action is that of causing the gas to pass in finely-divided streams through a body of water contained in a vessel, so that a portion of the ammonia and other gaseous impurities, and the whole of the floating particles of tar which have escaped condensation, may be removed before the gas enters the scrubbers. However

ample the usual condensing appliances may be, some portion of the lightest tar vapours escape their action. These are arrested in the washer, or tar-extractor as it is sometimes called.

This apparatus should always be used in conjunction with the scrubber, and the gas passed through it in the first instance. It is generally employed as a separate and distinct apparatus, but sometimes it is placed at the bottom of the tower scrubber of which it constitutes a part.

When the washer is exposed to outside atmospheric influence, it is necessary in winter to employ means to prevent the water from falling below a temperature of 50° Fahr.; otherwise the gas, especially a rich gas, passing through it, will suffer deterioration.

All washers give an amount of back pressure, varying from 1 to 4 inches, according to the depth of water traversed. There are numerous designs of the apparatus, but the principal ones are here described.

The persistent advocacy of Mr. George Anderson has done much to restore the washer to favour, and his form of the apparatus is still one of the best.

It consists of a cast-iron outer vessel, containing a number of trays, having on their under side a series of serrated bars extending from side to side; these dip into the water or liquor, and the gas, in passing through the serrations is divided into minute globules. The pressure given can be regulated by raising or lowering the overflow with which the apparatus is provided. A four-way valve is used for shut-off and bye-pass. Weak ammoniacal liquor from the condenser is run in at the top, and drips from tray to tray till it reaches the bottom. The washer is made either single or double as required.

In Cathels' washer the usual oblong or square vessel is divided into sections, as many as may be desired, each elevated higher than the others in the form of steps. The gas enters at the bottom, passes in divided streams through a number of curtain serrations extending the full length of the vessel, and so on through the rest, and out at the top of the higher compartment. When the liquor in the lowest section is of the strength required, it is run off, and the contents of the several sections transferred one step lower, the last or uppermost being charged with fresh water. This apparatus is also arranged in the vertical position to occupy less ground space.

Livesey's washer is a compact and efficient apparatus, occupying less room for the work done than any other. In a rectangular cast-iron box of any size (depending on the make of gas) is a series of rectangular tubes of wrought-iron, to which wrought-iron perforated plates are fastened, turned down at the sides till they dip into the liquor. The perforations are 1-20th of an inch diameter, and 1-5th of an inch apart.

The gas passes down between the tubes and through the side perforations into spaces filled with liquor, and, bubbling upwards, is again broken up by finding its way through the horizontal perforations into the open space above, and so along to the outlet of the apparatus. Means are provided for securing an active circulation of the liquor, which is constantly flowing through it from the adjacent scrubber, and away by an overflow to the well.

THE TOWER SCRUBBER.

The Tower Scrubber (Fig. 54) is a cast-iron vessel, either rectangular or cylindrical (the latter shape being preferred), erected on end, through which the gas is made to pass in an upward direction after issuing from the washer.

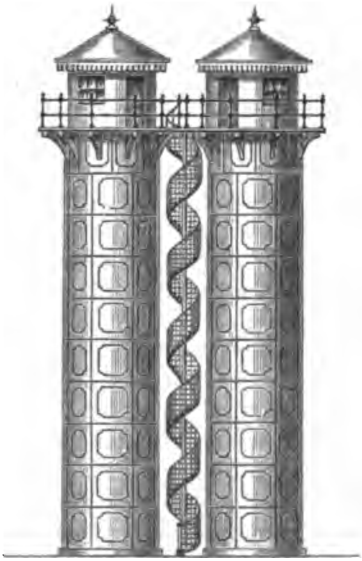


Fig. 54.

Its primary use is to purify the gas from ammonia by the aid of water; advantage being taken of the well-known great affinity of ammonia for that liquid. Water, at mean temperature and pressure (60° Fahr., barometer 30″), dissolves 783 times its volume of ammoniacal gas—that is, *undiluted* ammoniacal gas. When the latter is mixed with other gases, as in the case of coal gas, the power of water to arrest it is not nearly so great. It also arrests a considerable proportion of the sulphuretted hydrogen and carbonic acid.

This is accomplished by filling the vessel wholly or in part with either coke, boulder-stones, brick-

bats, roof or draining tiles, furze, or layers of thin boards set on edge, about 5 to 7 inches in width, $\frac{3}{8}$ths of an inch thick, and from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch apart; the material being kept constantly moistened by a stream of water trickling from a suitable distributing apparatus fixed in the crown.

When the coke or other material is placed in layers, it is supported on grids fixed at convenient distances apart; and opposite each space a manhole, secured by a movable lid or cover, is provided, so as to afford access to the interior, either for examination or renewal of the contained material.

The Livesey scrubber is fitted with boards $\frac{1}{4}$ of an inch thick, 11 inches wide, placed on edge, and kept apart by strips or blocks of wood $\frac{3}{4}$ of an inch square; thus making one board to 1 inch. The tiers are separated by 2-in. square cross sleepers.

The first cost of filling with boards is greater than when coke or other material is employed, but it possesses the marked advantage of not fouling up, and will rarely or never need renewing. The gas cannot form narrow channels in its passage through the vessel, but is constantly being broken up and brought in contact with the water that drips from all sides. Mr. Green uses canvas screens depending from transverse rods as filling medium. Open scrubbers are also used without any of the materials above mentioned. In such cases the column of gas in its upward progress is met by a descending shower of spray from a Gurney jet (Fig. 55).

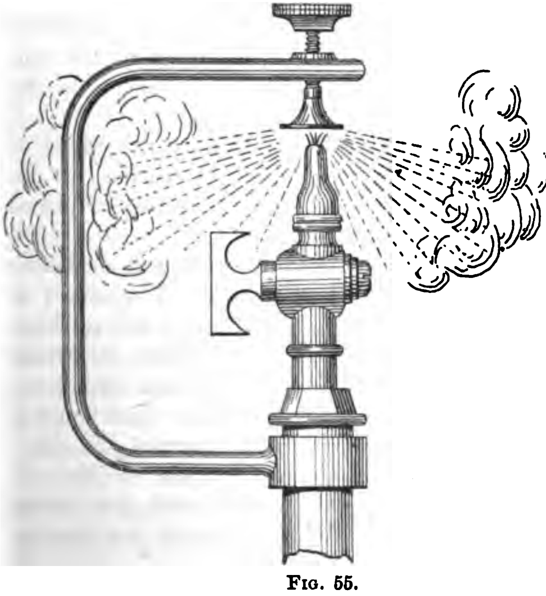


Fig. 55.

The most efficient tower scrubber is the cylindrical, standing in height about five

to seven times its diameter. Owing to the difficulty of securing an equal distribution of the water or liquor, the diameter should not exceed 10 feet in the largest works. As a general rule 8 feet diameter is preferable; for, to obtain the full benefit to be derived from this apparatus, there should be immediate contact of the gas with the water or liquor in a state of minute subdivision. Height is an important factor in a tower scrubber. Experience has proved that the best filling is thin rough-sawn boards, placed in alternate layers on edge one over the other, or canvas screens, as before described. When coke is used as the scrubbing material, it may be placed in six or eight layers, with a space of about 6 inches between each. Whatever material is used in filling the scrubber, it is important that all parts of its surface should be wetted as equally as possible. The proper action of the scrubber depends on this.

The necessity of a good water distributing apparatus is therefore obvious. Not only should this be of good construction in the first instance, but it should always be maintained in efficient working order. The gas enters at the bottom of the vessel, and the water or liquor at the top. The gas in travelling upwards is completely broken up, fresh surfaces being constantly presented to the descending drip, and to the wetted sides of the filling material, against which it is rubbed or scrubbed all the way up, until it emerges by the outlet at the top. A trapped overflow at the bottom conveys the liquor either to the washer or to the tar well.

The gas, before entering the scrubbers, should have the whole of the tar eliminated from it; and to ensure this, a washer or tar extractor may be employed, either as a separate apparatus, or placed in the bottom of the tower.

The weak ammoniacal liquor from the hydraulic main and condenser may be employed for distribution through the tower. The object of using this is to arrest a proportion of the carbonic acid and sulphuretted hydrogen, as well as the other sulphur compounds, for which ammonia has a strong affinity, thus relieving the lime and oxide purifiers, and saving labour and purifying materials. The weak liquor is also by this means brought up to the requisite commercial strength.

One method frequently adopted of applying the water or liquor is by a pipe passing through the crown or side of the vessel, from which pipe smaller tubes, pierced with holes, radiate towards the circumference. This may be either fixed or revolving; the latter being the

most efficient. In the Mann scrubber, the uppermost part of the tower containing the distributor is made about two or three inches wider than the rest, in order that the sides of the vessel may be wetted as well as the contained material. In this wider portion, and underneath the distributing tubes, there is a revolving layer of birchwood twigs lessening in depth towards the circumference, and the water falling upon this is equally distributed throughout. This arrangement requires the use of a small engine and gearing to produce the slow rotary motion.

To obviate the necessity for an engine, a Barker's mill or other similar appliance is sometimes used for producing the required motion; the mill is usually fed intermittently from a tilting box, or a vessel holding several gallons of water, and fitted with a valve and float. Where the quantity of liquor supplied is large, a small turbine may be adopted for turning the distributor. For small scrubbers, the water or liquor feeding arrangements may be as shown in Fig. 56.

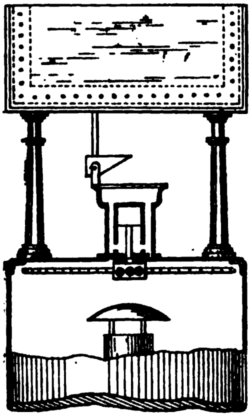


FIG. 56.

With the introduction and perfecting of the rotatory washer-scrubber has come a gradual modification of the views formerly held in regard to the superiority of the tower form. It is now generally admitted that the rotatory apparatus is of much excellence, being more under control, and more certain in its action, than the other. It by no means follows, however, that the tower scrubber should be discarded. The best provision to make for scrubbing purposes is to apply one tower and one rotatory apparatus for each stream of gas. That is to say: Assuming a works where the gas is sent in one continuous stream through the different appliances of purification, then one tower and one rotatory scrubber will suffice. Thus—

FIG. 57.

When the make is sent through the apparatus in several streams—

as should be the case in large works—the like provision is made for each stream. Thus—

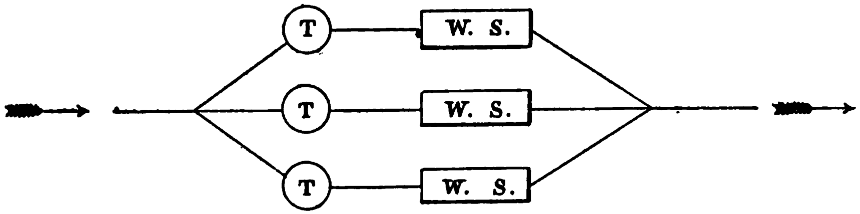


FIG. 58.

The question as to the capacity of the washer-scrubbers will be decided by the quantity of gas they are intended to pass; whether half, one, or two million cubic feet, and so on, per day of 24 hours.

Adopting this arrangement, the tower scrubber would be supplied exclusively with weak ammoniacal liquor, and the washer-scrubber with clean water. The tower scrubber, even in the largest works, should not exceed ten feet in diameter, for the reasons previously stated; the supply of liquor, which should be plentiful, being moderated or increased according to the season of the year and the quantity of gas being passed.

In works where there are no washer-scrubbers, but towers only, the latter are most economical and effective when they are used in pairs (Fig. 54), the gas being passed through first one and then the other. In such case, weak ammoniacal liquor should be pumped liberally through the first, and fresh water, in the proportion of two to three gallons per 1000 cubic feet of gas passing, through the second scrubber. When more than one pair of tower scrubbers is employed, as is the case in considerable sized works, the gas should be distributed in equal proportion through the several pairs simultaneously—not through each in succession.

Tower scrubbers, when used alone, and not in conjunction with the washer-scrubber, should have an aggregate cubical volume of at least 9 feet for each 1000 cubic feet of gas made per day of 24 hours, taking the *maximum* production as the basis of the calculation. For example, take a works producing in the depth of winter 600,000 cubic feet of gas per day of 24 hours:—

Then,

$600 \times 9 = 5400$ feet, cubical volume required.

This would be supplied by

Two scrubbers, each 8 ft. diameter, and 56 ft. high.

Or again, take a works producing 1,000,000 cubic feet per day:—

Then,

$1000 \times 9 = 9000$ feet, cubical volume required.

This would be supplied by

Two scrubbers, each 10 ft. diameter, and 58 ft. high.

Where the washer-scrubber is also employed, one tower in each of the above instances is sufficient.

THE WASHER-SCRUBBER.

The washer-scrubber has come largely into use in recent years, and deservedly so, as it removes the last vestige of free ammonia from the gas, as well as a proportion of the other impurities. It is placed horizontally, is rectangular or round in section, and consists of a cast-iron tank or vessel in divisions, containing water or liquor, in which a series of perforated discs or volutes of sheet-iron, or chambers containing wood balls or bundles, or other filling medium, exposing a large surface, are made to revolve on a central shaft, at a slow speed. These, as they rise from the liquid, are completely wetted on all sides, and the crude gas passing through or amongst them, coming in contact with the wet surfaces, is deprived of its ammonia and a portion of the other objectionable compounds. The clean or fresh water entering at one end, and flowing through the different divisions, is met by the gas which enters at the opposite end, and gradually increases in strength till it issues from the last compartment as 10 or 12 ounce (5° or 6° Twaddel) ammoniacal liquor. Kirkham, Hulett, and Chandler's "Standard" Washer-Scrubber (Fig. 59) and Laycock and Clapham's "Eclipse" Washer-Scrubber (Fig. 60) are of this type.

This apparatus has largely supplanted the tower scrubber, by reason of its being more manageable, as well as more certain in its action as an ammonia extractor. It is a mistake, however, to dispense altogether with the tower. The two should be used in conjunction, as described on page 95, the gas being drenched in the tower with weak ammoniacal liquor, and afterwards treated with clean water in the rotatory vessel. This is the perfection of gas scrubbing.

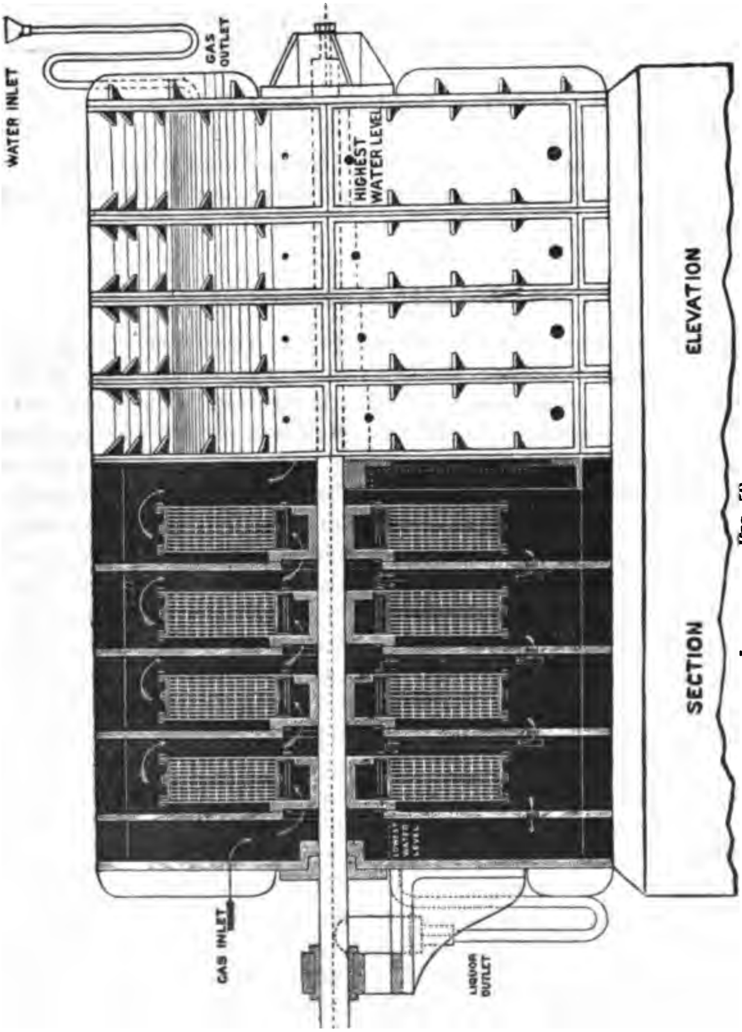

WATER INLET
GAS OUTLET
HIGHEST WATER LEVEL
ELEVATION
SECTION
LOWEST WATER LEVEL
GAS INLET
LIQUOR OUTLET

Fig. 59.

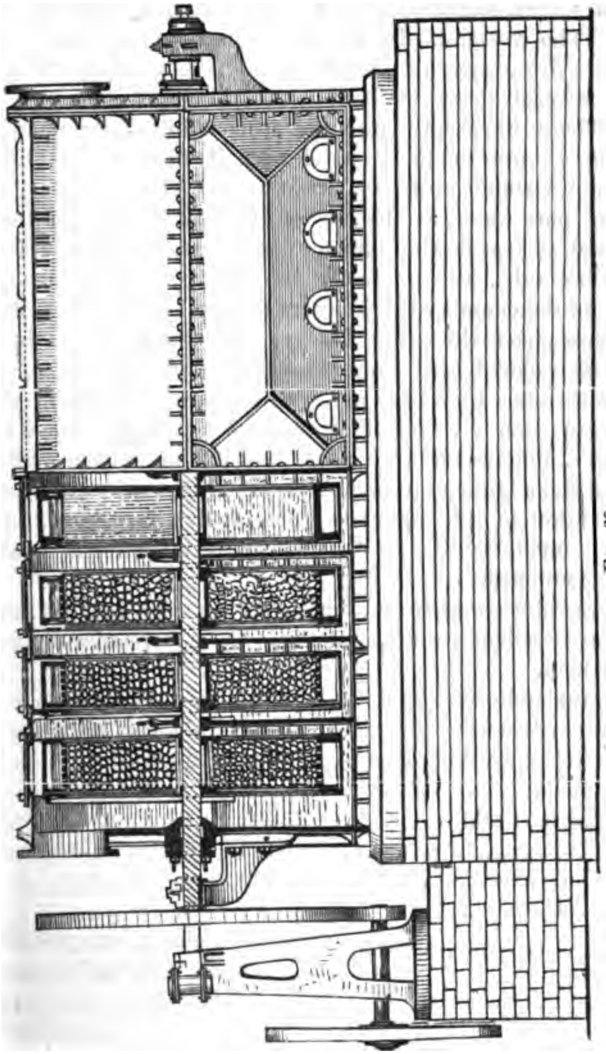


Fig. 60.

Anderson's combined washer and scrubber consists of a rectangular cast-iron vessel, standing on end, and in height about five times its width. The vessel is divided into compartments, each of which contains a drum caused to revolve by suitable gearing. The circumference of each drum is fitted with a brush of whalebone or other fibre. These fit exactly into the space allotted for them, and, in revolving, dip into the liquid which partially fills the several divisions. The scrubber stands on an Anderson washer (see page 91). A small stream of pure water, at the rate of 10 to 12 gallons per ton of coal carbonized, is kept flowing into the top compartment through a funnel and sealing tube, and gradually descends by way of the gas-pipes connecting the chamber till it enters the washer, from which there is an overflow pipe to the well. The gas enters the washer at the bottom, and is first relieved of the tar remaining after condensation; thence it passes through the revolving brushes, meeting different strengths of liquor in each division, till it reaches the upper one containing pure water, and away by the outlet. By this means the whole of the ammonia and a large proportion of the other impurities are removed.

In addition to the apparatus described above, the "purifying machine" made by C. & W. Walker is a powerful washer and scrubber combined.

Ford's scrubber-washer and Cockey's washer are compact apparatus, producing excellent results, and these do not require motive power to work them.

Dr. Frankland gives the following useful table showing the number of volumes of various gases which 100 volumes of water at 60° Fahr., and 30 inches barometric pressure, can absorb:

Ammonia	78,000 volumes.
Sulphurous acid . . .	3,300 ,,
Sulphuretted hydrogen .	253 ,,
Carbonic acid	100 ,,
Olefiant gas	12·5 ,,
Illuminating hydrocarbons	Not determined, but probably more soluble than olefiant gas.
Oxygen	3·7 volumes.
Carbonic oxide	1·56 ,,
Nitrogen	1·56 ,,
Hydrogen	1·56 ,,
Light carburetted hydrogen	1·60 ,,

When water has been saturated with one gas, and is exposed to the influence of a second, it usually allows a portion of the first to escape, whilst it absorbs an equivalent quantity of the second. In this way a small portion of a not easily soluble gas can expel a large volume of an easily soluble one.

BYE-PASS MAINS AND VALVES.

In connection with the foregoing apparatus, viz., the condenser, exhauster, washer, tower-scrubber, and washer-scrubber, bye-pass mains closed with valves or water-traps should be provided, in order to allow of any of them being put out of action for cleaning or repairs. The exhauster bye-pass is closed with a flap valve, so that, in case of sudden stoppage of the machinery, the valve opens by the pressure of the gas being thrown against it, and allows the gas to flow unchecked.

TAR AND LIQUOR WELLS AND TANK.

The tar and ammoniacal liquor underground wells may be built either of bricks laid in cement and carefully puddled at the bottom and sides, or of cement concrete rendered over the whole inside surface, or formed of cast or wrought iron or steel plates, bolted together, and having either planed or caulked or riveted joints. The iron vessel is preferable when the construction of a good foundation is likely to be a matter of great expense.

The well or wells should be of capacity sufficient to contain six weeks' make of material, reckoning from the maximum daily production. Less than six weeks' storage space will serve when the liquor is manufactured into sulphate of ammonia on the premises.

Another well of smaller dimensions, the size depending on the magnitude of the works, ought to be provided, to serve as a lute or seal, into which the drip-pipes from the different apparatus should dip. From this, at a depth of about 15 or 18 inches below the surface of the ground, an overflow-pipe or channel conveys the condensed products into the larger reservoir.

In some works the tar-pipe is taken direct from the hydraulic main into the large well, and there sealed by being made to dip into a vertical pipe secured to the bottom of the tank. This is objectionable, as, in case of stoppage, it is difficult of access. Again, there is always the liability of an escape of gas from that portion of the pipe within

the well; further, where flushing of the hydraulic main is practised, the rushing liquor carries with it a quantity of gas which is liberated within the well. It is also important that the tar should be cooled somewhat before entering the larger receptacle, because hydrocarbon vapour is given off from it at a temperature of about 90° Fahr. and above. In each of these cases the gas or vapour, mixing with the contained air within the well, would explode with disastrous consequences on contact with a light. Accidents which have occurred have been due to one or other of these causes.

In all cases the wells should be covered over to exclude surface and rain water, and prevent the possible loss of ammonia by evaporation.

In addition to the underground well, an elevated cast-iron cistern is indispensable in a well-appointed gas-works. Into this the

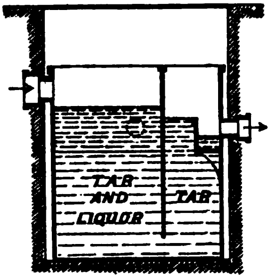


FIG. 61.—VERTICAL SECTION.

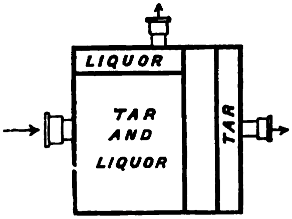


FIG. 62.—PLAN.

tar and liquor are pumped from the underground well, and suitable draw-off pipes, furnished with stopcocks or valves, serve to discharge the material into the barrels, trucks, or barges of the purchasing contractor.

The cistern may be divided in two by means of a partition plate reaching to within about 6 inches of the top, over which the ammoniacal liquor will flow, separating itself from the tar by reason of its lower specific gravity.

A tar and liquor separator, for placing in the ground in any convenient position near to the underground well, is shown in sectional elevation and plan in Figs. 61 and 62. It consists of a cast-iron vessel, about 4 feet square and 4½ feet deep, for a considerable sized gas-works. The division plate extends from the top of the vessel to within 4 inches of the bottom; the diaphragm, over which the tar

escapes into its separate well, being placed 1½ inches lower than the other diaphragm for the ammoniacal liquor.

TABLE.

Contents of Circular Tanks or Wells in Gallons for each Foot in Depth.

Diameter. Ft. In.	Gallons for each Foot in Depth.	Diameter. Ft. In.	Gallons for each Foot in Depth.	Diameter. Ft. In.	Gallons for each Foot in Depth.
9 0	397·6	16 6	1336·4	24 0	2827·4
9 3	420·0	16 9	1377·2	24 3	2886·7
9 6	443·0	17 0	1418·6	24 6	2946·5
9 9	466·6	17 3	1460·7	24 9	3006·9
10 0	490·9	17 6	1503·3	25 0	3068·0
10 3	515·7	17 9	1546·6	25 3	3129·6
10 6	541·2	18 0	1590·4	25 6	3191·9
10 9	567·3	18 3	1634·9	25 9	3254·8
11 0	594·0	18 6	1680·0	26 0	3318·3
11 3	621·3	18 9	1725·7	26 3	3382·4
11 6	649·2	19 0	1772·1	26 6	3447·2
11 9	677·7	19 3	1819·0	26 9	3512·5
12 0	706·9	19 6	1866·6	27 0	3578·5
12 3	736·6	19 9	1914·7	27 3	3645·1
12 6	767·0	20 0	1963·5	27 6	3712·2
12 9	798·0	20 3	2012·9	27 9	3780·0
13 0	829·6	20 6	2062·9	28 0	3848·5
13 3	861·8	20 9	2113·5	28 3	3917·5
13 6	894·6	21 0	2164·8	28 6	3987·1
13 9	928·1	21 3	2216·6	28 9	4057·4
14 0	962·1	21 6	2269·1	29 0	4128·3
14 3	996·8	21 9	2322·1	29 3	4199·7
14 6	1032·1	22 0	2375·8	29 6	4271·8
14 9	1068·0	22 3	2430·1	29 9	4344·6
15 0	1104·5	22 6	2485·0	30 0	4417·9
15 3	1141·6	22 9	2540·6	30 3	4491·8
15 6	1179·3	23 0	2596·7	30 6	4566·4
15 9	1217·7	23 3	2653·5	30 9	4641·5
16 0	1256·6	23 6	2710·8	31 0	4717·3
16 3	1296·2	23 9	2768·8	31 3	4793·7

PURIFICATION.

Impurities in Crude Coal Gas.—The chief impurities present in coal gas, in its crude or raw and unpurified state, at the time it leaves the retorts, are tar vapour, ammonia, carbonic acid, sulphuretted hydrogen, and other sulphur compounds, notably bisulphide of carbon.

The first-named impurity, tar vapour, begins to condense and is partially removed in the hydraulic main and pipes leading to the

condensing apparatus, where, if this is of sufficient capacity, and otherwise adapted to the performance of the work required of it, it is nearly all removed. What remains is taken out by the washer or tar extractor.

The ammoniacal gas, of which there is about 1 per cent. by volume, also begins to separate from the crude coal gas in the hydraulic and foul mains, combining with the moisture distilled from the coal. In the condenser and washer a further portion is removed, and in the tower scrubbers and washer-scrubbers, if these are as efficient as they ought to be, or can easily be rendered, the whole of the remaining ammonia (amounting to about ·15 per cent.) is extracted.

The hydraulic and foul mains, condensers, washers and scrubbers are also efficacious in removing a portion of the carbonic acid (existing in the gas to the extent of about 2·5 to 3 per cent.), sulphide of hydrogen or sulphuretted hydrogen (from 1 to 2 per cent. of which is contained in the gas), and bisulphide of carbon; but the bulk of these three latter impurities still exists in the gas after leaving the scrubbers, and is carried forward to the purifiers.

These are charged either with hydrate of lime or hydrated peroxide of iron, or a combination of both substances, arranged in separate layers or tiers within the several vessels.

Purification by Lime.—The lime has a perfect and strong affinity for carbonic acid and sulphuretted hydrogen, and accordingly it entirely removes these compounds from the gas, without leaving the slightest trace of their presence. The lime, however, in its state of oxide of calcium, has no affinity for the bisulphide of carbon, so that the greater proportion of this impurity (all, except such part as is removed by the foul lime when in the state of sulphide of calcium), is carried forward into the holders.

Cream or milk of lime was used in purifying in the early days of gas manufacture, and though this was thoroughly efficient, and is probably the most economical method of employing the lime, it has been generally discarded on account of the obnoxious character of the refuse material, "blue billy," as it was called, and the difficulty of getting rid of it. Lime in the hydrated state is now generally adopted.

The lime should be prepared by being slaked with clean water a day or two before it is required for use. If placed in the purifiers

before this necessary interval has elapsed, it is liable to cake or become more compact than it otherwise would. On the other hand, hydrate of lime absorbs carbonic acid from the atmosphere, and its purifying power is nullified in proportion to the extent of such absorption. It should not, therefore, be prepared for any great length of time before it is needed.

It is a mistake to place the prepared lime in the purifiers in a comparatively dry and almost powdery state. Lime used in this condition is less effective than when thoroughly moistened. It is also a wasteful method of using the lime, as a large proportion of the material will be found unspent and almost untouched by the impurities, when the vessel requires to be changed. The finely-divided lime is also more liable to cake than the other, and thus increase the back pressure. When the production of gas is great, as in the depth of winter, these disadvantages are strongly felt.

The lime should be well watered. A hose pipe or india-rubber tube, terminating in a copper spreader or rose, is useful for this purpose. It should then be passed through, by being thrown against, a screen made either of parallel steel rods ⅜-inch thick and 1 inch apart, or of strong wire having 1-inch square meshes. This not only removes the stones or flints which are less or more present, but it gives a granular character to the prepared material, in which condition it best performs its work in the purifiers.

Mr. Hislop has patented a process of calcination in suitable kilns, by which the spent lime is converted into quick lime to an almost unlimited extent, and at considerably less cost than new lime. A nuisance is thus got rid of, and further economy in purification effected.

Notes on Lime.—Limestone is the carbonate of lime found in its natural state, from which the oxide or calcium (quick or caustic lime) is produced by the expulsion of the carbonic acid by means of heat in the limekiln.

Quick or Caustic Lime (oxide of calcium) is lime in the solid state, before absorbing, or being slaked with, water.

Hydrate of Lime is lime in a moist state. It is a chemical compound of lime and water in the proportion of one part of water to three parts of lime.

Milk of Lime, or Cream of Lime, is a mixture or solution of hydrate of lime and water.

Quick lime nearly doubles in bulk on being slaked.

From 90 to 140 lbs. of quick lime, reduced to a hydrate, are required in the purification of the gas produced from 1 ton of cannel, and from 55 to 80 lbs. of that produced from 1 ton of coal.

1 bushel of quick lime	weighs about	70 lbs.	
1 cubic foot of ,,	,,	54 ,,	
1 ,, yard of ,,	,,	1460 ,,	
1 ton of ,,	is equal to about 32 bushels.		

The value of limestone as a purifying agent is in inverse proportion to the amount of earthy or foreign matter it contains; that which leaves the smallest proportion of insoluble sediment on being dissolved in diluted acid is the best.

Purification by Oxide of Iron.—Oxide of iron possesses the property of combining with sulphuretted hydrogen, but it has no affinity for carbonic acid and bisulphide of carbon; hence when this oxide is used exclusively, the two latter named impurities are still present in the gas as supplied from the holders. This remark, however, needs some qualification. As oxide of iron, pure and simple, it has no affinity for bisulphide of carbon and other sulpho-carbon compounds, but, from the observations made at the several metropolitan gas-works, Mr. R. H. Patterson (one of the Referees) deduced the interesting fact that the sulphur which is present in a state of minute division in the oxide of iron, after the latter has been in use for some time and frequently revivified, possesses the power of arresting a portion of the bisulphide of carbon.

The hydrated peroxide of iron may be either the natural oxide, bog iron ore as it is called, found largely deposited in some of the bogs in Ireland and elsewhere; or the artificial oxide, obtained as a waste product from various processes of the manufacturing chemist.

Oxide of iron possesses this advantage over lime: After it has been in the purifier, and has taken up its *quantum* of sulphuretted hydrogen, it can be revivified on exposure to the air. Accordingly, when this material is used, a floor has to be provided on which it can be spread out, and turned over for revivification. At the Manchester Gas-Works, a horse and plough are employed for turning over the foul oxide.

When taken out of the purifier it is sulphide of iron, of a dense black; and after exposure it changes to its original reddish brown colour.

oxygen having been taken up, and sulphur deposited in the free state in the mass. When the sulphur is found in it to the extent of about 40 to 60 per cent. by weight (the proportion depending on the quality of the oxide), the material is sold to the manufacturing chemist, and replaced by fresh oxide.

In using fresh oxide of iron, it is necessary to exercise certain precautions. The foul material, on its exposure to the air for the first two or three times, absorbs oxygen so rapidly as often to generate very intense heat, the whole mass frequently becoming red hot. Should this occur in the purifiers, the danger is considerable, and the wood grids may be completely destroyed. Whenever, therefore, a purifier containing such new oxide has been put out of action, it should be *emptied without delay*. The danger of ignition may be overcome by mixing the new oxide with a proportion of the spent.

Foul oxide should not be spread out immediately on being removed from the purifiers. If it is allowed to remain in the heap for a space of 12 to 24 hours, and then distributed over the floor, the revivification is more complete, whilst the liability to ignition is reduced.

Average Composition of the Richer Descriptions of Native Bog Ore for Purifying Purposes, dried at 212° *Fahr.* (*King's Treatise*):—

Ferric oxide	60 to 70 per cent.
Organic matter . . .	15 to 25 ,,
Silica	4 to 6 ,,
Alumina.	1 ,,

As generally used, the material contains 30 to 40 per cent. of water.

Purification by Lime, Sulphide of Calcium (Foul or Spent Lime) and Oxide of Iron, combined.—Lime alone, or the lime and oxide of iron, when properly applied, are capable of freeing the gas entirely of the whole three impurities, carbonic acid, sulphuretted hydrogen, and bisulphide of carbon. This brings us to the method of purifying expounded by the Referees in their Report to the Board of Trade on Sulphur Purification at the Beckton Gas-Works, January 31st, 1872; and also by Dr. Odling, somewhat more in detail, in his lecture on Sulphide of Carbon, delivered at the Annual Meeting of the British Association of Gas Managers, held in London, in June, 1872.

To accomplish this perfect purification in accordance with the suggestions made by Dr. Odling, three sets of purifiers are required; the gas passing through the first set into the second, and on to the third, from which it makes its exit through the station-meter into the holders. The *modus operandi* is as follows:—

Let it be assumed that three sets of purifiers, consisting of four vessels each, are employed. Nine of these are constantly in action, three being at rest (one from each set), for the purpose of changing or revivifying the purifying material.

The first and second sets are charged with lime, the third set with oxide of iron.

Say the whole nine are newly charged. On the gas from the scrubbers entering the first set, the lime is acted on by the carbonic acid and sulphuretted hydrogen simultaneously, leaving the bisulphide of carbon at the beginning of the process to pass unabsorbed. After they have worked for some time the sulphuretted hydrogen in the first set is gradually expelled by the incoming carbonic acid, for which the lime has a stronger affinity. The second set is now being fouled with sulphuretted hydrogen, the lime being wholly or in part changed in character, having become sulphide of calcium, in which state it has an affinity for, and consequently arrests, the bisulphide of carbon; whilst the unabsorbed sulphuretted hydrogen passes on to be taken up by the oxide of iron with which the final set of purifiers is charged. By the application of the proper tests at the several sets of purifiers, the time for changing the material is ascertained.

The question of supplying gas entirely free from sulphur in any form is a formidable one for gas companies; not so much because of the cost (though that is considerable) of erecting the additional sets of purifiers, as from the difficulty of providing the necessary ground space for their erection. In new works about to be constructed the thing is easily arranged; but in the majority of works already established it would not be easy to carry the system into effect.

As regards the question of cost, a careful estimate shows that to adopt the extended method of purifying as enunciated, would entail an outlay of additional capital equivalent to close upon 2d. per 1000 cubic feet of gas sold.

The property of absorbing or arresting bisulphide or disulphide of carbon possessed by the sulphide of calcium, was known by chemists

and some observant managers of gas-works for a period considerably anterior to the date of the publication of either the able report of the Referees, or of the valuable lecture of Dr. Odling, and the principle of purification, therein recommended, acted on to some extent. Dr. Letheby, in a paper communicated to the British Association of Gas Managers in 1870, speaking of the mode of purification pursued at the Great Central Works, and, after referring to the scrubbers, goes on to say, that "the gas is then passed through a series of dry lime purifiers, which present a very large surface for absorption; and the lime is purposely left in the purifiers after it has become foul, and until a good deal of the sulphuretted hydrogen first absorbed is displaced by carbonic acid. In this manner the natural affinity of sulphide of calcium for bisulphide of carbon is permitted to act, and much sulphur, in this objectionable form, is retained. Leaving the lime purifiers, the gas, which is still charged with more or less of sulphuretted hydrogen, is passed through oxide of iron. . . . . The chemical effect of these operations is very intelligible, for sulphide of ammonium (in the scrubbers, &c.) and sulphide of calcium are both endowed with the power of combining with bisulphide of carbon, and therefore of absorbing and fixing this objectionable impurity. It is manifestly then of the greatest importance that coal gas should be kept in contact with these substances as long as possible during the process of purification. . . . In the case of sulphide of calcium, it should be permitted to act for some time after the lime has become foul, for it is in this condition that it is most effective, and a lime purifier should not be changed until the sulphuretted hydrogen of the foul lime is largely displaced by the carbonic acid of the raw gas. If it be necessary to use oxide of iron on account of the difficulty of disposing of foul lime, it should be used after the lime."

It remained, however, for Mr. R. H. Patterson to show, which he did conclusively, that this complete purification can only be successfully attained by first extracting the carbonic acid, as, until that is entirely removed from the crude gas, it is impossible to obtain the sulphide of calcium in sufficient quantity or condition to arrest the bisulphide of carbon.

The Use of Air in Purification.—By drawing in a measured quantity, say 1½ to 3 per cent., of air at the inlet to the condenser, revivification of the oxide of iron *in situ* can be effected to a large extent.

The purifiers are thus made to continue in use for a greater length of time without changing, whilst it is remarkable that the oxide by this process can be charged with as much as 75 per cent. of free sulphur.

Purifiers with a proportionately large area in comparison with the make of gas are required to obtain the full advantage of this process.

In adopting the air process, two layers of oxide are preferable to one deep layer. Owing to the heat generated by chemical action, as well as to the deposition of the sulphur, a considerable increase or expansion in the bulk of the material takes place in the purifiers, and it is necessary, therefore, to allow ample room for the oxide to expand. A space of several inches should be allowed between the two layers, and the surface of the upper layer should be at least three inches below the edge of the water lute.

To counteract the effect of the nitrogen passing into the gas (the oxygen having entered into combination with the purifying material), and reducing the illuminating power, Mr. J. G. Hawkins has devised an apparatus for carburetting the air. This consists of a closed cast-iron box, oblong in shape, which is constantly supplied with tar from the hydraulic main or condenser, the tar being heated by means of steam pipes at the bottom of the box, to a temperature of 176° Fahr. (the boiling point of benzole). Air is forced by means of a steam pump through the box over the surface of the tar, being made to pursue a tortuous course by means of a series of baffle plates, and is then permitted to join the stream of gas at the condensers; so that any subsequent condensation of hydrocarbon vapour is returned to the tar well.

The Use of Pure Oxygen in Purification.—The chief objection to the use of air for revivifying the oxide of iron *in situ* is the importation of a considerable volume of the inert gas nitrogen into the gas, reducing the luminiferous value of the latter, unless counteracted by the carburetting process above described.

It is obvious that if pure oxygen is employed instead of atmospheric air, the objection stated will be overcome. The cost of producing oxygen, however, rendered its use prohibitory for this purpose until the advent of Brin's process for the production of pure oxygen from atmospheric air on a commercial scale and at a cheap rate.

In a valuable paper read before the Gas Institute in 1888, Mr. Valon gave an interesting description of a series of careful experiments

carried out by him to test the value of the system of adding pure oxygen to the gas in the process of purification by oxide of iron or lime.

The oxygen was admitted at the exhauster outlet by a pipe connected to a wet meter to register the quantity passing, and to a small holder in which the oxygen was contained.

The quantity of oxygen passed into the oxide was ·1 per cent. by volume for every 100 grains of sulphuretted hydrogen per 100 cubic feet of gas.

There was found to be an increase in luminosity of about 5 per cent., whilst the purification was conducted with less than the usual quantity of purifying material and purifying space.

Using lime only in the purifiers, the results were still more satisfactory. It was found that the sulphur was deposited in the solid form, the lime being perfectly carbonated.

The sulphur compounds were kept down to an average of 6 to 8 grains per 100 cubic feet; and the illuminating power of the gas was raised by 1·25 per cent.

In order to obtain the pure oxygen by Brin's process, air is first deprived of its carbonic acid and moisture by being drawn by a pump through chambers containing lime and caustic soda, and the same pump forces it, under a pressure of about one atmosphere, through barium oxide, contained in steel retorts 8 inches in diameter, heated in brick furnaces to a dull red heat by producer gas. At this temperature the barium oxide absorbs a large proportion of the oxygen contained in the air, and is converted into barium peroxide; the nitrogen, and any unabsorbed oxygen, escaping through a relief-valve at the other end of the retorts. When the barium oxide is sufficiently peroxidized, the temperature of the retorts is raised to bright red, and the pumps, by the changing of the valves, are converted into vacuum pumps; thereupon the absorbed oxygen, under the influence of the higher temperature and reduced pressure, is given off again, and discharged by the pumps into the gasholder. The retorts containing the restored barium oxide are allowed to cool to their previous dull red temperature, when the barium oxide is again ready to abstract a fresh supply of oxygen from the air. With due care, and under proper conditions, there seems to be practically no limit to the number of operations which may be effected by the one charge of barium oxide.

Such was the method of working at the time when Mr. Valon read the paper referred to. The practical process, however, as since perfected by him, and the one in use wherever Brin's method of obtaining oxygen is relied on, is to maintain the retorts containing the barium at one temperature, say about 1250° to 1300°. When the air is being pumped into the retorts it is kept under a pressure, governed by a safety valve, of about 15 lbs. to the square inch ; and when the pumps are reversed the pressure is converted into a vacuum of 15 lbs. This alternate pressure and vacuum is governed by an automatic arrangement attached to the eccentric of the engine driving the air pump, so as, in point of time, to pump in for two minutes under pressure, and to pump out for three minutes under vacuum; each complete operation thus taking about five minutes.

The reason for keeping the retorts at one temperature is to overcome the difficulties attending the raising and lowering by alternately using a vacuum and a pressure, as, in practice, nothing that could be devised would withstand the movement caused by alternately raising and lowering the temperature two or three hundred degrees. No doubt, as Mr. Valon says, the latter is the ideal way, which, in practice, cannot be carried out. The only drawback to adopting the new and practical method of working is that, while as much oxygen can be got out in the same given time, the purity cannot be maintained at as high a standard. By alternately heating and cooling it is possible to get 95 per cent. of purity ; with the pumps about 88 per cent.

The cost of the oxygen obtained, including interest on capital for plant, wear and tear, and all manufacturing expenses, is given by Brin's Company at 5s. per 1000 cubic feet.

Other Methods of Purification.—Continuous purification, like continuous carbonization, is a dream of both chemists and gas engineers which has not yet been realized. Various attempts have been made to accomplish it, but hitherto without success. The processes suggested and tried are full of interest, and it is worth while referring to them.

Mr. R. H. Patterson patented a process of purifying by washing or scrubbing the gas in solutions of caustic soda and sulphide of sodium, extracting the carbonic acid and sulphur impurities, and so dispensing altogether with the ordinary lime and oxide of iron purifiers. The soda solutions, when saturated with the impurities, possess the important quality of being easily and perpetually revivified or

restored to their original state on the gas-works, whilst the whole of the sulphur is secured for sale. The plan, however, has not been tried on an adequately large scale.

Attempts have been made by Mr. Laming, Mr. Livesey, Mr. F. C. Hills, and others, to purify the gas in closed vessels by employing the ammonia found in the gas for arresting the other impurities. Unfortunately, the loss of ammonia at each time of desulphurating the liquor, owing to its extreme volatility, prevented success in this direction under the conditions adopted.

Claus's Process.—This process of continuous purification in closed vessels, though not hitherto practically successful, is of such importance and promise as to merit a detailed description.

The crude ammoniacal liquor, consisting of sulphide of ammonium and carbonate of ammonia, is passed through a series of towers, wherein it is exposed to the action of carbonic acid (obtained as described below), whereby the sulphide of ammonium is decomposed, sulphuretted hydrogen being liberated, and carbonate of ammonia remaining alone.

The sulphuretted hydrogen passes through and out of the towers in the opposite direction to that in which the crude liquor travels, and is disposed of in the manner described hereafter, whilst the carbonate of ammonia solution passes forward into other towers in which it is heated to a temperature of 180° to 200° Fahr.

At this temperature the carbonate of ammonia, of a strength equa to 10 or 15 ounce liquor, loses two-thirds or three-fourths of its carbonic acid, and a corresponding quantity of caustic ammonia remains in the liquor passing from these towers.

As only a portion of the carbonic acid evolved in the heating vessel or towers is required for the above-mentioned decomposition of sulphide of ammonium, the surplus is allowed to escape in a regulated quantity, and may be used for other purposes forming part of the process.

The sulphuretted hydrogen, after leaving the towers, is conveyed to a closed furnace charged with oxide of iron, where a low incandescent heat is generated and maintained by the admission of a regulated supply of air.

The oxide of iron, once heated, continues to absorb the sulphuretted hydrogen, which, owing to the continual admission of air, is evolved in the form of sulphur, in finely-divided particles, which is carried off

and caught in chambers, so that the oxide does not require revivification, and the same quantity, kept hot by continual working, goes on indefinitely decomposing the sulphuretted hydrogen sent through it.

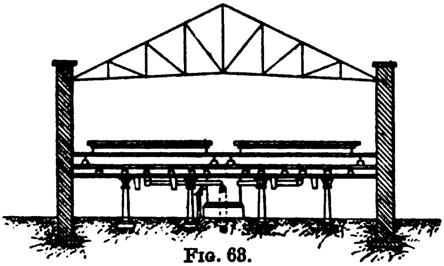


FIG. 63.

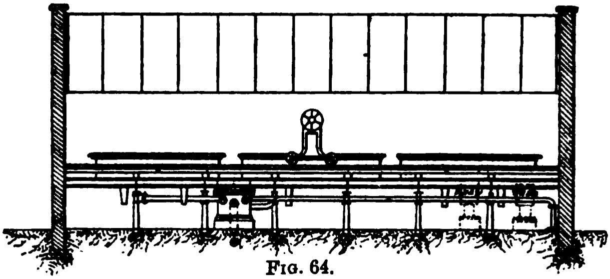


FIG. 64.

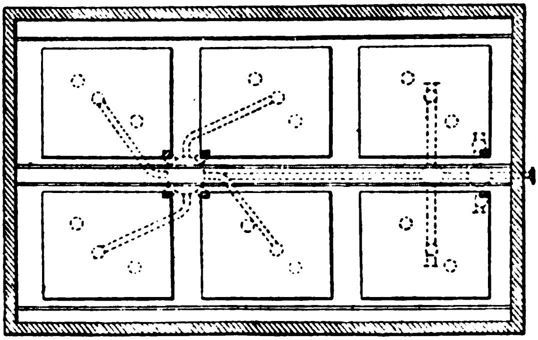


FIG. 65.

The purified ammoniacal liquor is then passed down distilling towers, into which steam is admitted, driving off the ammonia gas at the top, which is passed through cooling chambers in which any carbonate of ammonia carried with it deposits in crystals.

Thence, as much of the ammonia gas as is required for the purposes of purification, passes with the coal gas into a chamber, where they are allowed sufficient time to mix.

The gas is then passed through scrubbing towers, where all the impurities are washed out in the liquor, which may be obtained of 40 to 50 oz. strength if required.

Any surplus ammonia, being perfectly pure, can be used for making any of the salts of ammonia desired.

The liquor flowing from the bottom of the distilling towers contains sulphocyanide of ammonium, and may be used over and over again in the scrubbers instead of water, until the sulphocyanide accumulates to such a strength as to make it marketably valuable for chemical manufacture.

Purifying House.—The house to contain the purifiers should be lofty and well-ventilated, not only for the comfort of the workmen employed therein, but to lessen or entirely remove the risk of explosion from any leakage of gas that might occur. The house should also be arranged with a view to future extension.

It is a convenient plan to build the house with a ground and upper floor, and to place the purifying vessels on the latter with the connections and centre or other valves underneath and fully exposed and accessible. The ground floor can thus be used for revivifying the oxide of iron, if that material is employed, or for other purposes. (Figs. 63 to 68.)

The vessels are discharged through an opening in the bottom of each, closed by a gas-tight lid, and the fresh material is raised by means of an endless chain ladder, or other suitable elevating apparatus, to the floor above. (Figs. 66 to 68.)

Purifiers.—The purifying vessels are almost invariably made of cast-iron, with sheet-iron covers secured with suitable fastenings to prevent their being lifted by the inflowing gas pressing on their under surface.

Malam's arrangement of four in the set, with connections and a centre-valve (Fig. 69), by which three of the vessels are kept in action, and one out of use for renewal of the purifying material, is still generally adopted, and is the simplest and most convenient. In some works a second set of two purifiers is used in addition to the series of four, and these are connected together, and to the others, with single or four-way valves. (Fig. 69.) Under this arrangement the set of

four is charged with oxide to arrest the sulphuretted hydrogen, and the set of two with lime to take up the carbonic acid, the gas passing through them in the order shown.

In determining the size of purifiers, where either dry lime or oxide of iron is intended to be used, it is of the utmost importance to

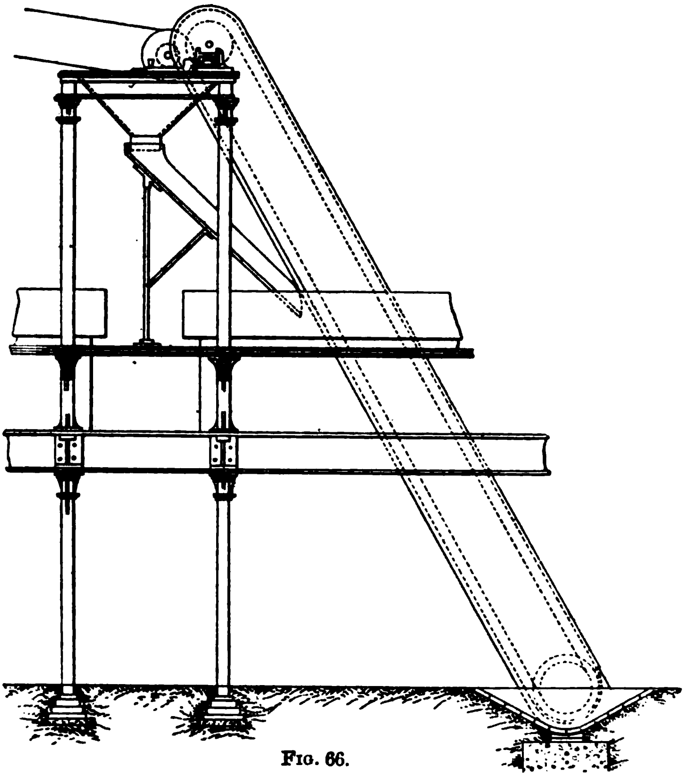


Fig. 66.

provide a liberal superficial area, and to make ample allowance for increased gas-make.

One of the greatest sources of discomfort to a gas manager is having his purifiers so cramped and confined in their area as to be incapable of doing the work required in an efficient manner.

The ordinary and best form of purifier is the square or oblong; this shape is the cheapest, affords the largest area for the space occupied

and is also the most convenient as regards the placing of the trays or grids.

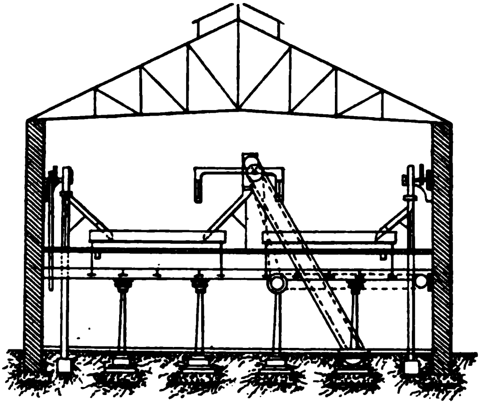


FIG. 67.

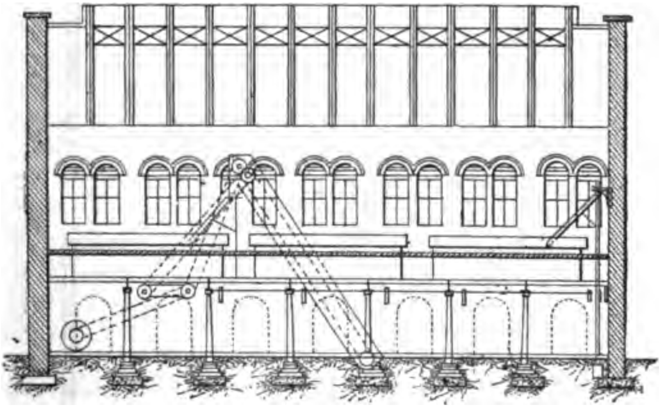


FIG. 68.

The usual depth of purifiers is 5 feet; in some large gas-works they are 6 feet deep.

Purifiers, say, 20 feet square and upwards, should have two or more tie rods of round wrought-iron stretching across them from side to side, at the upper part of the lute, to support the sides under the strain to which they are often subjected by the expansion of the

contained oxide of iron, especially where the air process, previously described (page 110), is in operation. These ties should be removable,

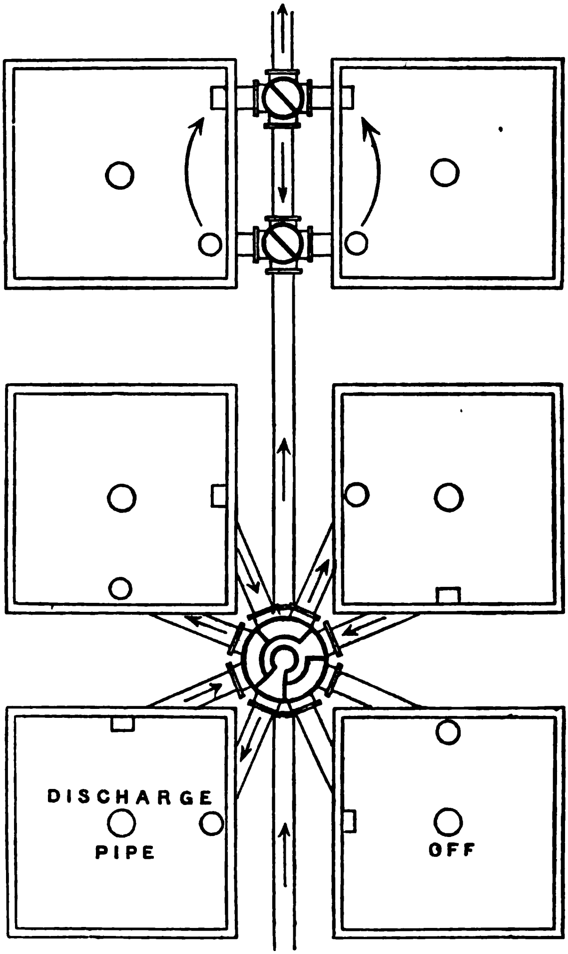


Fig. 69.

having an eyelet hole at both ends, fitting into a forked piece, also furnished with eyelet holes, bolted to the vertical flanges, and secured by an easy fitting bolt or pin.

The capacity or purifying power of the vessels is determined more by

their superficial area than their cubical volume. There is, however, a mutual relation between the two, as, when the depth is increased and fully utilized, the surface area has to be proportionately augmented, on account of the resistance offered by the deeper material to the flow of the gas. It is more strictly correct, then, to say that the superficial area, in proportion to the depth of the purifying material, is the gauge of the capacity or purifying power of the vessels; and the maximum hourly or daily gas-make of which the works are capable should form the basis of any calculation to determine their size.

One of the chief conditions for securing satisfactory purification is the use of vessels of large area. If economy and efficiency are to be considered, *time* is an important element, and must not be disregarded. The mere passing of the gas through the purifying media is not sufficient in itself to insure good results; time, or what is the same thing in this case, lengthened contact is required, for chemical affinity to operate.

Rule for the Size of Purifiers.—Where there is intended to be four purifiers, three always in action, the maximum daily (24 hours) make of gas, expressed in thousands, multiplied by the constant ·6, will give the superficial area in feet of each purifier.

Example.—Required the superficial area of each of the four purifiers in a works equal to the production of 500,000 cubic feet of gas per diem of 24 hours.

$500 \times \cdot 6 = 300$ feet superficial area of each purifier.

$\sqrt{300} = 17 \cdot 3$ (say, 18) feet side of square of purifier.

For very small works where there is no exhauster, the constant ·8 may be employed with advantage.

Water Lutes.—The evils of contracted area in purifiers are aggravated by having a shallow seal to the lids or covers and the hydraulic centre-valve—if such be used.

In small works the lute should never be less than 12 inches deep by 4½ inches wide; and in medium sized and large works, from 18 to 30 inches in depth by 6 to 8 inches in width.

Ample depth of water lute is especially important where the back pressure is increased by the use of telescopic holders.

Layers of Purifying Material.—In purifiers charged with hydrate of lime, there may be two or four tiers of sieves. The lime spread upon their surface may be from 4 to 8 inches in depth.

When oxide of iron is used, the layers may be two in number, and the material 15 to 20 inches deep on each.

It is a mistake to adopt the plan of placing either the lime or oxide in a single deep layer. The gas is apt to form passages through the deep material; whereas when there are two or more layers of less depth, it recovers itself and changes its course through each.

Sieves, Trays, or Grids.—Round wrought-iron rods, $\frac{3}{8}$ of an inch thick, bound together with a framing of angle or flat-iron, make an excellent tray, especially where lime is used; they are less suitable for oxide of iron, which destroys them by corrosion, though when made of the strength named, they last for many years. They possess a great advantage over most other trays in the smaller space which they occupy in the purifier, and the larger purifying area obtained by their use. Perforated cast-iron and wood trays are suitable for either lime or oxide. The latter are usually made with strips of wood (yellow pine, pitch pine, or red deal, the prices being as 3, 2, 1) of any convenient length; the strips are $1\frac{7}{8}$ inches broad, $\frac{1}{2}$ an inch thick, and slightly tapered, the outer pieces of frame being of harder timber (hickory, beech, oak, or ash), and $1\frac{1}{4}$ inches thick; the whole bound together with $\frac{3}{8}$-inch bolts and nuts, having the heads, washers, and nuts countersunk in the side frames, and the holes plugged with wood or cement. The strips are kept $\frac{1}{2}$ an inch to $\frac{5}{8}$ of an inch apart by pieces of wood of that thickness, and $1\frac{7}{8}$ inches square, put between them at the places where the bolts are inserted (Fig. 70).

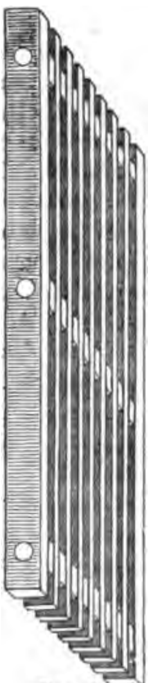


FIG. 70.

Apparatus for Raising the Lids or Covers.—For raising the lids or covers of the purifiers, various contrivances are employed; the most common being a double purchase crab, travelling on rails laid on either wooden beams or iron lattice girders, having their ends inserted in the walls of the building; or in the absence of walls, supported on pillars. Another arrangement consists of a traveller extending across the purifying house from wall to wall, traversing the length of the house on rails fixed on each side to a beam or girder supported by projecting corbels. On this again there is a lifting crab also on rails, and the gearing of both crab and traveller is actuated by chains from the floor of the house.

The lifting machine, sometimes called a "Goliath" (Figs. 71 and 72), first constructed by Messrs. Cockey and Sons, is a useful and com-

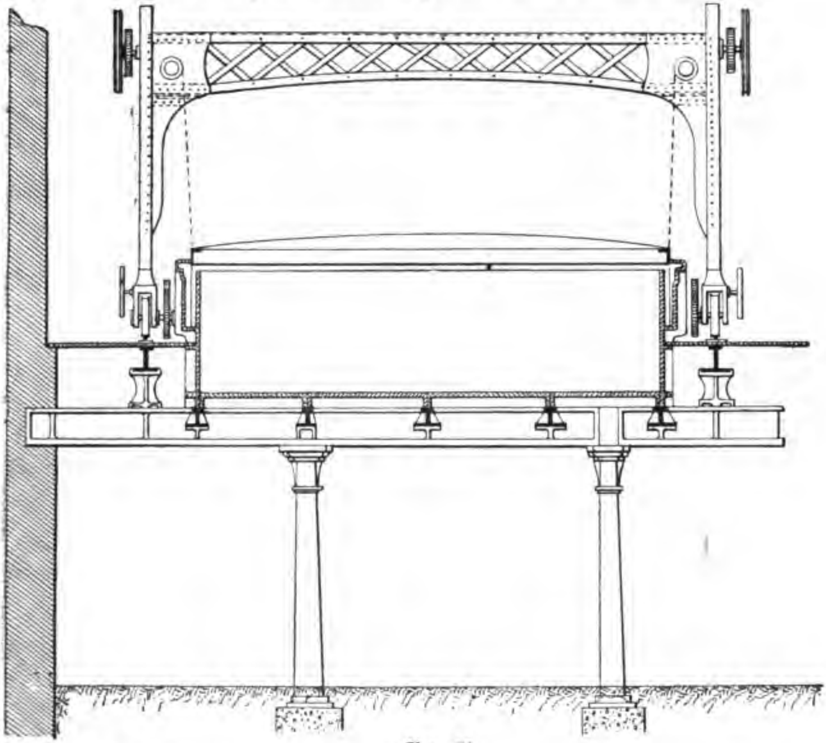


FIG. 71.

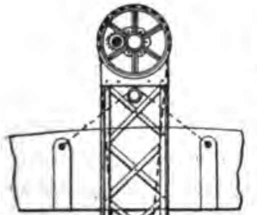


FIG. 72.

pact contrivance for the same purpose. This consists of two standards, one on each side of the purifier, connected across the top by two girders a few inches apart. The standards, having grooved or flanged wheels, or rollers attached, traverse the purifying house from one end to the other on rails laid on the floor, The covers are raised by means of two long vertical screws, with an eyelet-hole at the end of each, in which the hooks on the lid are inserted, and moved by a winch and

cog-wheels put in motion by means of a handle at one of the sides. When the apparatus is not in use, it can be wheeled out of the way, leaving the space above the purifiers to the tie-rods or beams of the roof entirely unobstructed. A somewhat similar traveller, in which hydraulic power is applied instead of the wheel gearing and screws, is sometimes employed for accomplishing the same object.

The most compact and efficient lifting arrangement for lids of large size is that of the direct acting hydraulic ram, the head of which is

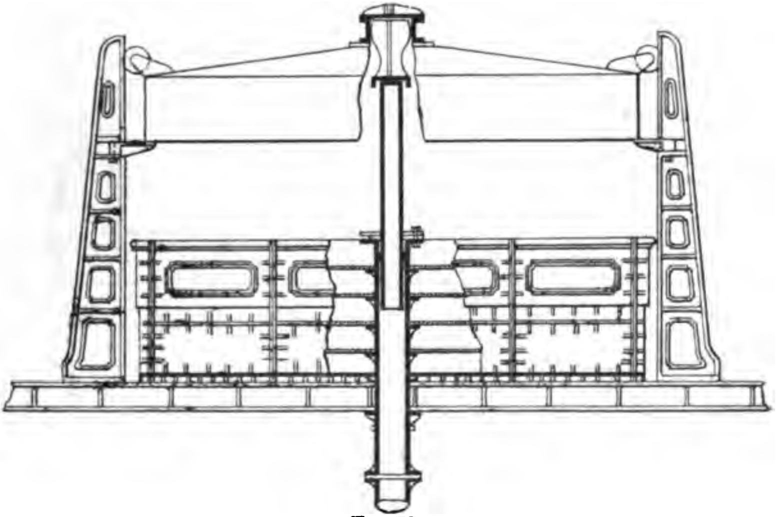


FIG. 73.

attached to the centre of the lid, and on the application of water pressure to the ram by means of a hand or steam pump, the lid is raised to the required height. (Fig. 73.)

Centre and other Change Valves.—The dry centre-valve, with surface faced to fit gas-tight, is now extensively adopted, and, as a rule, is preferred to the old hydraulic centre-valve. The chief advantages it possesses over the latter are the greater ease and facility in changing from one purifier to another, one man being able to accomplish this with a few turns of a handle, thus minimizing to the utmost extent the passage of unpurified gas during that operation. It occupies less space, is entirely beneath the purifying-house floor, and presents a dead resistance to pressure admitting of greater steadiness

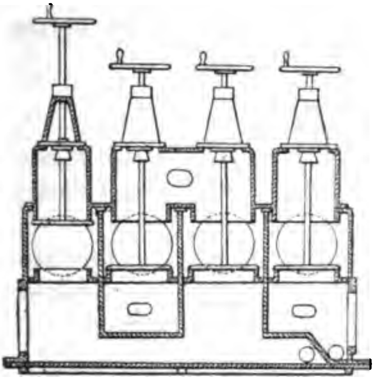


FIG. 74.

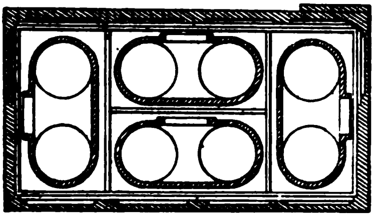


FIG. 75.

in the flow of the gas where an exhauster is at work. But it has its drawbacks. In the larger sizes especially it is liable to lose its tightness on the slightest disturbance of the foundation either by subsidence, or the action of frost, and even by the weight and pressure of the connecting pipes. The Weck valve (Figs. 74 and 75), which consists (for a set of four purifiers) of eight valves within a frame or box, is both handy and efficient, and for large connecting pipes is preferable to the foregoing.

Four-way valves are adopted by some managers in preference to the centre-valve, their chief recommendation being that by their use the connections are simplified. The advantages which they possess over the ordinary single valve are more apparent. When the latter are employed twelve are needed for a set of four purifiers, and six for a set of two; whereas, with the four-way valves, only one-third that number is required.

Size of Connections.—With respect to the size of the connecting-pipes, the rule is to make their internal diameter, *in inches*, equal, as nearly as possible, to the square root, *in feet*, of the area of the purifiers.

Thus, purifiers 10 feet square, giving an area of 100 square feet, have connecting-pipes 10 inches in diameter; and purifiers 16 feet by 12 feet, having an area of 192 square feet, have their connecting-pipes 14 inches in diameter. With the larger proportionate sizes of purifiers now being employed over those formerly erected, a deduction of $\frac{1}{8}$ may safely be made from the result obtained by the above rule. Thus (see rule on p. 119), a works capable of producing 500,000 cubic feet of gas per day requires four purifiers, having each an area of 300 square feet [$500 \times \cdot 6 = 300$], the square root being 17·3; deducting $\frac{1}{8}$,

or 2·2, we have 15·1, or, say 15 inches, the diameter of the connecting-pipes.

CLASSIFICATION

Of the best known Limestones of this Country, in the Order of their Purity, and which Order also expresses their Value for the purpose of Purifying Coal Gas. (Hughes.)

1. The white chalk limestone of Merstham, Dorking, Charlton, Erith, and other parts of the chalk range surrounding the metropolis.
2. The grey chalk limestone, from the lower beds of chalk.
3. The blue beds of the upper and middle Oolites.
4. The lower white and grey limestones of the Oolites.
5. The most calcareous and crystalline beds of the carboniferous or mountain limestone, colours grey and bluish.
6. The magnesian limestone of Yorkshire and Derbyshire.
7. The white lias limestone.
8. The blue lias limestone.
9. The Silurian limestone of Wenlock, Dudley, &c., and the coralline limestones of Plymouth and the neighbourhood.

TABLE

Showing the Composition of Different Limestones and their Specific Gravity. (Government Commission.)

	Quality of Limestone and Locality.	Carbonate of Lime.	Carbonate of Magnesia.	Silica (Flint.)	Iron Alumina (Clay.)	Water and Loss.	Specific Gravity (Dry.)
Oolites.	Ancaster, Lincolnshire . .	93·59	2·90	..	·80	2·71	2·182
	Bath Box, Wiltshire . . .	94·52	2·50	..	1·20	1·78	1·839
	Portland, Dorsetshire . .	95·16	1·20	1·20	·50	1·94	2·145
	Ketton, Rutlandshire . .	92·17	4·10	..	·90	2·83	2·045
Lime-stone.	Barnack, Northamptonshire	93·40	3·80	..	1·30	1·50	2·090
	Chilmark, Wiltshire . . .	79·00	3·70	10·40	2·00	4·20	2·481
	Ham Hill, Somersetshire .	79·30	5·20	4·70	8·30	2·50	2·260
	A trace of bitumen was observed in each of the above.						
Magnesian Limestone	Bolsover, Derbyshire . .	51·10	40·20	3·60	1·80	3·30	2·316
	Huddlestone, Yorkshire .	54·19	41·37	2·53	·30	1·61	2·147
	Roche Abbey do. .	57·50	39·40	·80	·70	1·60	2·134
	Park Nook do. .	55·70	41·60	..	·40	2·30	2·138

Other Analyses.

	Quality of Limestone and Locality.	Carbonate of Lime.	Carbonate of Magnesia.	Silica (Flint.)	Iron Alumina (Clay.)	Water and Loss.	Analyst.
Magnesian Limestone.	Denton, near York . . .	68·0	30·0	..	2·25	0·25	Holme
	Eldon	52·0	45·2	..	1·1	1·7	Davy
	Aycliffe	45·9	44·6	..	1·57	2·8	do.
	Portishead, near Bristol.	58·5	37·5	..	0·8	3·2	Gilby
	Four Miles N.W. of Bristol.	58·0	38·0	1·5	1·1	1·4	do.

Analyst:	Quality of Limestone and Locality.	Carbonic Acid.	Lime.	Alumina.	Silica.	Bitumen.	Water and Loss.	Iron and Clay.	Magnesia.
Tennant	Magnesian, of which York Minster is built	47·00	33·24	..	..	..	..	0·40	19·36
Clarke.	Carboniferous, Whiteford, Flintshire	40·10	49·65	8·80	0·60	0·60	0·25	..	..

Lime Burning.—This subject is not of absorbing interest to the gas manager in this country, because there is always an abundant supply of lime to be had for the ordering without any need for concern as to how it is produced. But to such as undertake the management of gas-works in some places abroad, it is desirable that they should make themselves familiar with a process which they may have to practice as a matter of necessity or for the sake of economy.

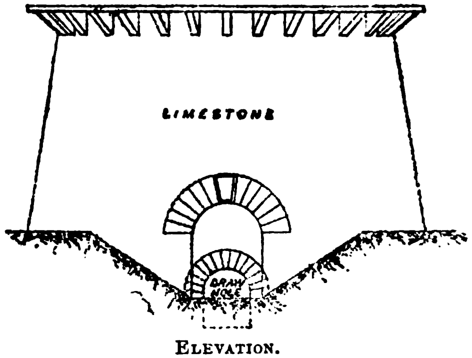
Limestone or carbonate of lime, in some form or other, exists in almost every part of the globe, from the fat or rich qualities down to the lias or hydraulic kinds. These latter are not suitable for gas purification, as they contain an excess of earthy or clayey matter in their composition.

The substance existing in the limestone which gives it its peculiar character of hardness and durability, inasmuch that it resists denuding atmospheric influences almost as effectually as granite and more so than most classes of sandstone—is carbonic acid gas. The chemical formula for limestone is $CaCO_3$. The object of burning or calcining the limestone, as is well known, is to expel the water, which is

mechanically held in it, and the carbonic acid, CO_2. The quicklime or oxide of calcium being left, its formula is therefore CaO. The equation representing the effects of the process of calcination is $CaCO_3 = CaO + CO_2$. Curiously enough, the water which is present in ordinary limestone when it is first broken in pieces, and not dried by exposure to the air, assists the calcination of the material by promoting the escape of the carbonic acid.

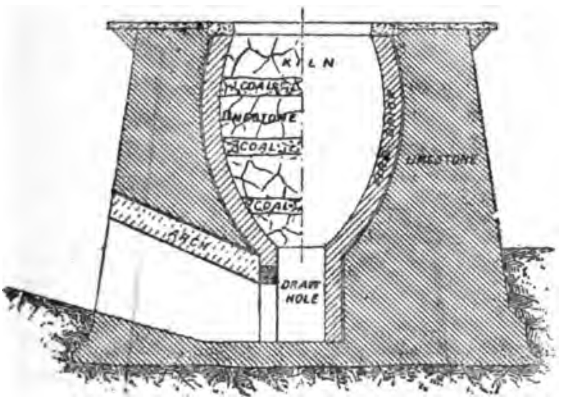
The crudest method of burning lime, and that practised by half-civilized peoples, is to range the materials on the ground in alternate layers with coal, wood, turf, or other fuel, surrounding them with clay or clods of earth to retain the heat; a firehole being left in the bottom, and an opening made in the apex of the heap to allow of the escape of the gas. Fire being applied to the fuel, it is allowed to burn itself out, and the process is complete. This, as might be supposed, is the least economical plan to adopt; the quantity of fuel required bearing an undue proportion to the bulk of lime produced.

Lime kilns are constructed in various forms; but whatever form they take, they are resolvable into two classes—viz., tunnel kilns and flare kilns; the former having the coal or other fuel and limestone arranged within them in alternate layers, and the latter being fired without allowing the fuel to come in contact with the lime. Either of these may be perpetual or draw kilns—that is to say, they may be kept constantly at work by removing the calcined lime from the drawhole at the bottom, and adding fresh material at the top; or the fuel may be fired, and the charge allowed to burn itself out, and become cool before discharging the lime.



ELEVATION.
FIG. 76.

A small form of tunnel kiln is shown in Figs. 76 and 77. The lining is of fire-brick, 9 inches thick throughout; but this does not always extend to the top, and in some examples the lining is en-



SECTION.

FIG. 77.

tirely of gritstone a foot thick. Between the lining and the outer masonry, a cavity 2 inches wide is left—being filled in with ground stone, ashes, or other yielding material — to admit of the expansion of the lining by the heat without rending the structure.

In charging the kiln, a layer of brushwood or other easily-igniting fuel, is placed at the bottom to assist the kindling of the coal at the beginning. Then comes a layer of coal about 4 or 6 inches thick. After that a layer of limestone 12 to 16 inches deep, in pieces ranging in weight from 2 lbs. to 20 lbs.; the largest being placed in the centre, and so on. The stratification of the materials in alternate layers is continued till the kiln is completely filled, when the fire is lighted, and the burning or calcining process is begun. In the perpetual or draw kilns, where the operation is carried on continuously, so long as the kiln lasts, the burned lime is raked out through the draw-hole at the bottom. The mass gradually subsides, filling up the void; and fresh fuel and limestone are added at the top.

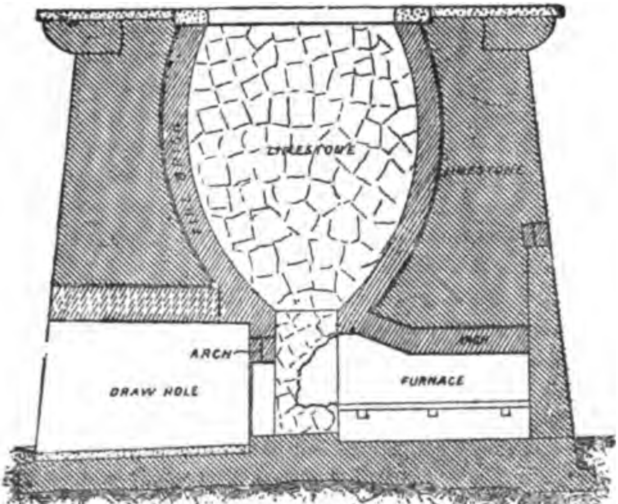
The flare kiln, shown in Figs. 78 and 79, is the more cleanly of the two, the firing substance being kept apart from the lime; but it is not as efficient and certain in its action as the tunnel kiln where the material is placed in alternate layers.

In course of burning, the stone is heated to redness; and when the whole of the carbonic acid has been expelled, the redness disappears, and the quicklime, or oxide of calcium, is left in rich white floury lumps.

The proportion of coal used varies according to the obdurate nature of the limestone. In some instances one measure of coal serves for four of the stone; but in others it takes about one ton of coal to burn two

ELEVATION.

FIG. 78.



SECTION.

FIG. 79.

tons of the stone. On the average, three bushels of lime are produced for each bushel of coal consumed. In the case of other fuels: a similar weight of gas-works coke, mixed with one-fourth small coal, is needed, and of wood and turf one cubic foot of limestone requires 1½ cubic feet of these in the burning.

The product known as "lime ashes," is the breeze of the kiln, and consists of small and dusty lime mixed with the ashes of the fuel.

In countries possessing a scanty supply of limestone, calcareous spar and oyster and other shells found on the sea coast are calcined into quicklime, which is produced as a fine flour.

It only remains to be said that the quicklime on its removal from the kiln is stored in sheds under protection from the weather. On its being slacked with water, it evolves much heat, crumbling or falling, and becomes hydrate of lime; its formula being CaH_2O_2, in which condition it is ready for the purifiers.

THE STATION METER AND OTHER INDICATING AND RECORDING APPARATUS.

The most important of the recording appliances in a gas-works is the station meter. The house containing this should be conveniently situated on the works, and made sufficiently large to contain, if possible, in addition to the meters, the station governors, exhaust and pressure registers, a range of pressure gauges, and a jet photometer. When thus arranged they are all within the purview, and immediately under the control, of the workman in charge. The meter house is susceptible of ornamentation, and should have a little bestowed upon it, besides being kept scrupulously clean and well ventilated.

Station Meter.—The quantity of gas manufactured as it passes into the holders after its purification has been completed, is measured and recorded by the station meter.

This is invariably of the "wet" description: that is to say, the measuring wheel is caused to revolve by the elastic force of the gas pressing upon the surface of a body of water, with which the vessel is charged up to a certain line.

In construction it differs slightly from the wet meters used by consumers, but its principle of action is identical with these.

Pressure Gauges.—The ordinary pressure gauge (Figs. 82 and 83) has its tubes, which are of glass, charged with water to the zero line on the ivory or boxwood scale between. This is graduated into inches and tenths. It is made of any length as required, and the scale may be figured either in inches or tenths of an inch, as shown.

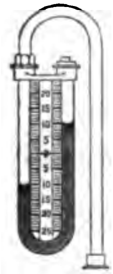


Fig. 82.


Fig. 83.


Fig. 85.

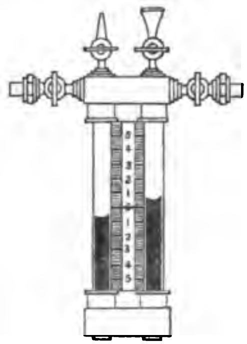


Fig. 84.

On the gauge being attached to the main or service pipe, either directly or by means of a short connecting tube, the difference between the two water levels represents the gas pressure in terms of a column of water.

A series of these gauges, to indicate the pressure existing between the different apparatus of the gas-works, should be fixed in some position convenient for frequent inspection.

King's gauge (Fig. 85) is constructed on the same principle as the above, but it indicates slighter variations of pressure; the finger having a long sweep for small differences of water level, and the dial being graduated into finer divisions.

The differential gauge (Fig. 84) is commonly attached to the inlet and outlet pipes respectively, of station meters; the indications of the instrument being the difference in pressure between the two, showing the pressure absorbed in actuating the meter.

Coloured water for pressure gauges is made by infusing a little pounded cochineal in hot water. It is then filtered, and a few drops of nitric or hydrochloric acid added, to prevent the bright scarlet colour from fading.

The glass tubes of pressure gauges, when foul, may be cleansed with a weak solution of sulphuric acid in water.

Pressure and Exhaust Registers.—The principle of action of these instruments (Fig. 86), invented by Crosley, is the same as that of the foregoing, but they are made to *record* as well as *indicate* the pressure or exhaust, as the case may be.

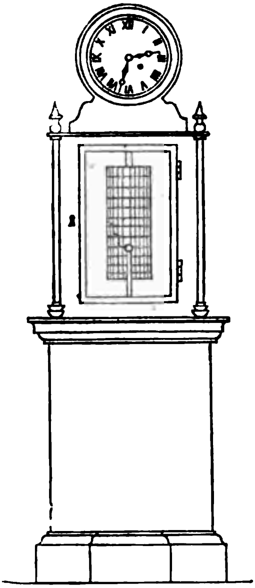


FIG. 86.

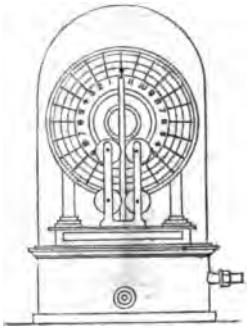


FIG. 87.

This is accomplished by means of a float in water, to which a vertical spindle is attached, having a lead pencil at the upper end, pressing upon a cylindrical graduated roll of paper upon a drum, which is caused to revolve by clockwork once in the 24 hours. The paper roll is renewed daily.

The exhaust register is connected to the mains on the works at a point between the hydraulic main and the exhauster, and the record shows, whether, in the absence of the manager, the exhauster has been kept working with regularity.

The pressure register is attached to the street main beyond the governor, and records the various pressures maintained therein during the day and night.

The difference between the exhaust and pressure registers is simply one of detail in construction : the zero line in the former being placed midway on the scale, and the spindle lengthened to correspond, whilst the area of the float is also increased. In the latter the zero line is at the bottom.

Wright's pressure register (Fig. 87) is a combination of the King's gauge, with a time-piece having a circular plate and paper disc instead of a dial. The 24 hours are printed on the disc, and a pencil at the end of a rod actuated by the float, pressing upon this, records the varying pressures.

Mr. W. H. Cowan has invented a neat and compact instrument which records the pressures by photography upon sensitized sheets on the revolving cylinder, instead of by the markings of the usual lead pencil.

THE GASHOLDER TANK.

The tank is that portion of the storage reservoir for gas which contains the water in which the floating vessel or holder rises and descends. (Figs. 88, 89, 90.)

Ground *line.*

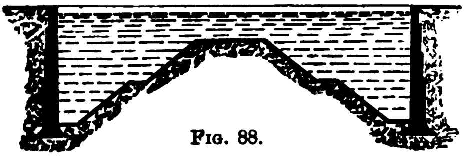
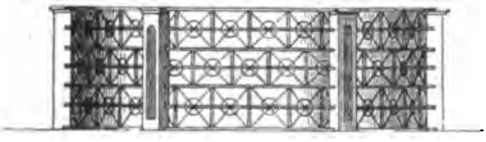


FIG. 88.



Ground *line.*

FIG. 89.

Ground *line.*

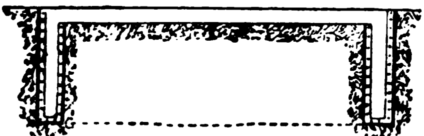


FIG. 90.

It may be constructed either wholly or partially under the ground level, or (as in the case of iron tanks) entirely above ground (Fig. 89).

The first thing to be done, in determining the site of a tank, is to sink a well or shaft in the vicinity, or to make a number of borings on or near to the site, in order to ascertain the character of the strata in which the excavation for the proposed tank has to be made. If the ground in the immediate neighbourhood is clear of other tanks or buildings, it is not a matter of serious concern to find that a bed of sand, full of water, has to be encountered. To overcome a difficulty of that kind in such circumstances, is chiefly a question of pumping power. Piling also might be resorted to, and the free use of concrete, in case there is a possibility of the water being removed by pumping from underneath the tank at any future time. But, on the other hand, if there are adjacent structures which it is unwise to run the risk of damaging, then it is well to be chary about pumping the water from the underlying sand and gravel. In such event, it is almost a matter of certainty that the removal of the water, accompanied also by the removal of a large proportion of the sand along with it, would cause subsidence of the ground in the vicinity, with consequent, and possibly irreparable, damage to the structures upon it. The safer and more prudent thing to do in such a case is either to abandon the site for another; or, if that cannot well be done, to construct the tank either wholly or partially above-ground, and of cast or wrought-iron plates.

Assuming that the site for a gasholder tank has been finally settled; that it has been decided the tank shall be constructed of masonry (which term includes stone, brick and concrete, or a combination of these); that it has been ascertained by boring that water is present in objectionable abundance in the substrata to be pierced—the first thing to be done is to sink a well or sump, 8 to 4 feet in diameter, at a convenient distance from the circumference of the proposed excavation. This should be lined with open unmortared brickwork (technically called "steining"), to allow of the free percolation of the water into the sump or well through the joints of the lining. Into this, when the sinker has reached the water-bearing strata, he conveys the suction-pipe of the pump, puts the latter in operation, and clears out the inflowing water to enable him to proceed with his work. This well is carried down to a depth of 8 to 5 feet (depending on the volume of water present), below the bottom of the intended excavation, and is then paved with bricks set in cement. If the strata are of uniformly open character—consisting, say, of a mixture of gravel and

sand—one sump will be sufficient to clear the ground of water; otherwise, if it is not uniform, but barred by intervening clayey deposits (not an unusual thing), and even by solid-bedded sand—for this sometimes is almost as impervious as clay—it may be necessary to drain the water to the sump, or even to put down two or more sumps outside the ground operated on. Duplicate pumps should be provided where the inflow of water is very great. With these arrangements completed, the work of excavating and building can be proceeded with unhindered by the presence of any undue amount of water.

In the course of practice, the excavation for a tank of which the writer was engineer was chiefly through hard sand-stone rock, the layers of which had been tilted up into almost the vertical position. This was fissured and cracked in all directions; and through the crannies, water bubbled up in numberless springs. Although one side of the adjacent ground was at a lower level than the tank bottom, it was impossible, by any reasonable expedient, to draw off the water from the outside. Possibly, by sinking a shaft to a considerable depth, it might have been accomplished. But considering the nature of the strata, that would have been costly; so other means were resorted to to overcome the difficulty. It is not an easy thing—in many cases it may be pronounced to be impossible—to choke out water from a tank from the inside. In puddling the bottom of the tank in question, and covering the puddle with a bed or layer of concrete, the springs were by no means closed; and though they were reduced in number, the flow of water was still quite as plentiful as before. Assuming that the pressure in these springs was sufficiently great to have overcome the pressure of the head of water in the tank when the latter was full, there would have been no objection to leaving them to flow unhindered. But that was a risk which it was not prudent to run. The head of water in the tank would probably have more than counterbalanced the pressure of the springs; and where water can enter, it can as easily make its exit. The plan which in this case was adopted for making the tank water-tight, was to train or drain the different streams of inflowing water to one point by cutting a trench round the side of the bottom where the springs occurred, and laying therein strong 3-inch drain pipes, which in turn were carefully protected by a covering of strong concrete. The springs usually occur at, or near to, the base of the mound or dumpling left in the tank bottom; so that it is easy to gather them together by a drain and convey the water all to

one convenient point. There was now only one stream of inflowing water to deal with; and at this point was placed a 8-inch cast-iron stand-pipe, 3 feet in length, closed by a valve at its upper end, and the flanged foot secured by four Lewis bolts let into a base-stone 18 inches square and 9 inches thick, through the centre of which a hole was drilled. This stone was let into the floor slightly below the level of the concrete surface; and a cavity was left underneath it. From this stand-pipe, the inflowing water was pumped to relieve the pressure on the bottom till the cement in which the stone was bedded had set hard. It should be mentioned that, in the side of the stand-pipe, at distances of 9 inches apart, there were three ¾-inch holes drilled. These were left open, to allow the water to issue from them without rising to the top. As the filling of the tank proceeded, these holes were each carefully plugged as the water rose above them; then the valve on the upper end of the stand-pipe being closed, the filling with water was completed—the tank proving to be perfectly water-tight.

Another method sometimes adopted, instead of using a stand-pipe as described, is to carry the drain right through the tank wall at its base, thus making an outside exit for the water. The stand-pipe, however, is preferable as being more self-contained and certain in its action. It sometimes happens that, without previous indication of its presence, the pressure of surrounding water will, in the course of construction, blow a hole or holes in the tank bottom. If so, the best thing is to let it blow; let it have free vent until all is completed and the tank ready for water, then apply the stand-pipe as described.

In another instance, the line of circumference of a tank came close up to the side of a retaining wall bounding a considerable stream. In this case, the excavation having to be carried close up to the wall, the latter was laid bare for about 30 feet of its length; and as the cutting had to be taken about 6 feet below the level of the water in the stream, the rush of water through the interstices of the wall would have been fatal to the operations. Accordingly, to shut out the water, a wall of wooden sheet-piling was constructed—a cofferdam, in fact—60 feet in length; and the wooden piles forming one side of it were shod with iron, and driven (most of them) 12 feet into the bed of the stream. They were then bound together at their upper ends by a horizontal beam bolted thereto, and anchored at distances 10 feet apart with long bolts passing through the retaining wall. The space between the piling and the stone wall was two feet in width, and was hand-dredged to a depth

of ten feet below the water level. This space was carefully filled in to above the stream level with stiff clay puddle, well rammed down. The work was eminently successful; and it was found an easy matter to cope with any water from the stream that reached the excavation, either from beneath or from beyond the two ends of the cofferdam.

The presence of water in an excavation is not always objectionable, unless it be excessive in volume. For example, in excavating through stiff clay, it renders the work of the labourer much easier than if the ground is dry and hard. Those who have had experience in shifting boulder clay, will readily endorse this view. Strata of this character are often so hard and parched and intractable as to require blasting to facilitate removal.

Avoid puddling a tank-bottom in wet weather, especially if the bottom is in the form of a mound or cone. Uniformity of consistence in the puddle is of more importance here than against the outside of the walls, for the obvious reason that the bottom has to bear the pressure of the water when the tank is filled. If one portion is well consolidated and firm and another soft and yielding, the concrete covering is liable to crack and split open, owing to the unequal sustenance. It is almost impossible to preserve this necessary uniformity with water coursing down the slope of the mound; the puddle becoming sodden and sloppy. The fact that equal sustenance is of such importance, also proves the necessity of having the clay covering on the bottom of one uniform thickness all over. Even the deeper excavation made to receive the horizontal portions of the inlet and outlet pipes should have a solid concrete filling, allowing for just a like thickness of puddle above them as over the other parts of the apron and cone.

It is not a wise thing to test the tightness of a tank with water immediately on completion. Better wait till the holder is finished, in order to give the puddle and cement time to set before subjecting them to the heavy pressure of water. We have known several instances of the splitting of tanks due to this premature filling with water. Further, before filling a tank with water for the first time, the puddle and backing behind the wall should be carefully watered—by means of a hose-pipe, if possible—for several days before the filling is begun, and also during its progress. This promotes consolidation of the backing.

In excavated tanks, wherever the substratum is favourable, it is economical to leave a circular or conical mound in the centre. This is called the "dumpling" or "cone" (Fig. 88).

Tanks are occasionally formed by making a circular cutting in the ground, and erecting therein an iron or brick annular channel to contain the water, the intervening central space being also covered with water, but of a less depth, depending on the extent to which the subsoil has been removed. This central space requires to be covered with a layer of concrete, and the surface rendered with Portland cement. These are called annular tanks. See Fig. 90.

Excavation for Tank.—The width of the excavation for a tank depends on the nature of the substrata encountered, whether clay, shale, gravel, sand, &c., unless a complete system of close-shoring by means of timber all round is adopted. The best method is to sink a trench 12 feet wide all round the circumference, and close-timber both sides of the excavation. Where the ground is yielding and soft, or saturated with water, the vertical shoring-timbers may be 7 inches wide and 8 inches thick; the waling pieces double, and 8 feet apart, 11 inches by 8 inches, and the struts 9 inches by 6 inches, in cross section. This will afford substantial support.

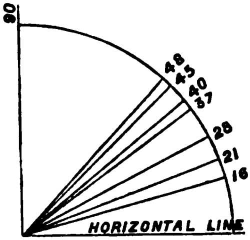


FIG. 91.

Natural Slope or Angle of Repose of Earths with Horizontal Line.

(Fig. 91.)

Sand, dry . .	average	37°	or 1·88	to 1
Sand, damp . .	,,	21°	,, 2·68	,, 1
Shingle and gravel .	,,	40°	,, 1·2	,, 1
Clay, drained . .	,,	45°	,, 1·0	,, 1
Clay, wet . .	,,	16°	,, 3·3	,, 1
Earth, compact .	,,	48°	,, 0·9	,, 1
Peat or vegetable earth	,,	28°	,, 1·89	,, 1

Weight of various Earths and Rocks.

	Per Cubic Yard.		Per Cubic Yard.
Sand, dry .	about 2480 lbs.	Marl . .	about 2900 lbs.
Sand, damp .	,, 3200 ,,	Shale . .	,, 4370 ,,
Shingle and gravel	,, 2850 ,,	Chalk . .	,, 4000 ,,
Clay . . .	,, 3240 ,,	Sandstone . .	,, 4250 ,,
Mud . . .	,, 2700 ,,	Slate . .	,, 4860 ,,

Materials of which Tanks are Constructed.—Tanks are constructed of stone (either built up, or excavated from the solid rock) brick, concrete, cast or wrought iron, or a combination of iron with the other materials.

The kind of material employed is regulated, as a rule, by the character of the district where the gas-works are situated, and the nature of the ground whereon the erection is to be. If the neighbourhood abounds in stone, the probability is that that will be the cheapest, and will consequently be adopted in the construction of the tank. But even in districts where stone is plentiful, if this is of a hard nature, the expense of dressing is such as to make the tank more costly than if built of bricks, though the latter may have to be brought from a distance. In places distant from a supply of building material, and to which the latter has to be brought by conveyance, brick will generally be chosen as the most suitable.

On the other hand, where the ground is of such a character as would entail an extraordinary outlay in securing a good foundation, or where it is unsafe for a brick or stone structure; or, again, where the sinking of a tank is almost impossible, owing to the presence of a large body of inflowing water through the strata, as by the sea-side, or contiguous

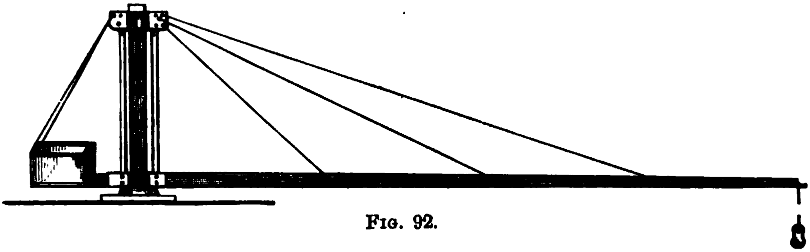


FIG. 92.

to some rivers, the best class of tank to be adopted is one made either of cast or wrought iron, or steel plates bolted or riveted together, the cast-iron plate joints being either planed or made water-tight with rust cement. It is only under such circumstances that iron tanks are adopted, as their cost is greater than either brick or stone, and the erection of a tank above ground is disadvantageous in several respects.

It may happen that the ground is of such a nature as to render the construction even of an iron tank upon it unsafe; or there may be a slope or embankment in dangerous proximity. In such cases recourse may be had to piling to give it solidity and prevent movement.

In the construction of a tank the use of a trammel to insure accuracy in the circle is indispensable. In Fig. 92 is shown a convenient form of this apparatus.

When the tank is of large diameter, say 140 feet and above, the movable arm of the trammel is necessarily long and heavy, and in such case the centre post may be a steel lattice girder stayed with wire guy ropes. The apparatus should remain in position and use until the tank coping is fixed. In addition to the trammel, wood templates 16 feet long, made to the proper curve on their outer edge, should be provided and frequently applied to the surface of the wall as it rises.

Masonry tanks, being porous, are generally built with a backing of clay puddle behind the walls and in the bottom; but the puddle can be dispensed with by lining the tank with a coat of neat Portland cement about 1 inch in thickness. Mortar composed of cement and clean sharp sand in equal proportions by measure, makes a water-tight lining, provided it is carefully polished to a smooth face with a steel trowel.

A lining of 4½-inch brickwork, with a space between the tank wall and the lining, 1 inch wide, filled with neat cement or asphalte, is also occasionally adopted.

The walls of a tank so treated, being impervious to water, require to be made somewhat stronger, and the backing more carefully consolidated, than where puddle is employed, because there is no fluid pressure outside to balance the fluid pressure within the tank.

The weakest part of a masonry tank, as usually constructed, is that where the inlet and outlet pipes pass through the wall at the bottom. The instances of failure here are so numerous as to justify

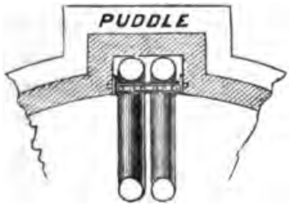


FIG. 93.

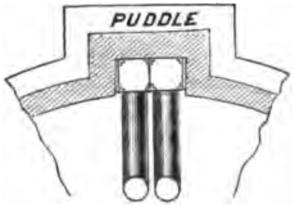


FIG. 94.

the plan, sometimes adopted, of placing the pipes in a recess built in the tank wall. The objection to this recess is that it breaks the circle of the wall, and consequently weakens its power of resistance to outside pressure; but continuity of the circle can be secured by strutting the opening with cast-iron struts as in Fig. 93.

Or the pipes can be made square in section, and built in with the wall, as in Fig. 94.

When a brick or stone tank built in blue lias lime mortar is of large dimensions, the walls may be strengthened at intervals of 2 or 3 feet apart, by rings 2 or 3 feet in width, of the brick or stone laid in Portland cement mortar.

Hoop-iron, or flat wrought-iron rings, built at intervals into the masonry or concrete, are occasionally used for giving strength to the walls of a tank. When the diameter is great, and particularly in tanks where no puddle is employed, flat bar-iron hoops, braced or tightened by screws or cotters, are also sometimes placed round the outside.

When from any cause it is found impracticable or undesirable to construct a masonry tank, whether of stone, brick, or concrete, with its coping on a level with the adjacent ground, circumstances may require that the raised portion of the wall should be strengthened, in addition to the support given by the earth backing, either by flat wrought-iron or steel rings built into it, or by outside wrought-iron or steel hoops. One such ring or hoop will suffice for every 4 feet in height of the tank wall above the natural ground level. The strength of the iron will, of course, be determined by the dimensions of the tank; but it may be stated, by way of guidance, that for a tank of 102 feet in diameter, the iron should be 5 inches wide and $\frac{3}{4}$ of an inch thick. The flat ring is made continuous throughout the circle by riveting, and the hoop by screw-bolts or cotters.

The bricks used in building a tank should be thoroughly well wetted before being laid, to cause the mortar to adhere.

In time of severe frost all brick and stone work should cease.

To prevent injury in time of rain, and especially in winter, when a sudden frost might supervene, the top of the new walling should be covered with weather boards.

Concrete.

	By measure.
Blue lias lime concrete (for foundations)—	
Gravel, shingle, broken stone, bricks, or old retorts, $1\frac{1}{2}$ to 2 inches cube	6 parts.
Clean sharp sand	2 parts.
Blue lias or other hydraulic lime	1 part.
Portland cement concrete (for tank walls)—	
Gravel, shingle, broken stone, bricks, or old retorts, $1\frac{1}{2}$ inches cube	7 parts.
Clean sharp sand	2 parts.
Portland cement	1 part.

Mr. J. Douglas gives the following useful instructions for mixing or preparing the concrete :—" A platform, about 20 feet square, of deals, should be laid on the ground to ensure the clean mixing of the materials. The measure for the material is simply a square box without top or bottom, and should contain, as a convenient quantity, about half a yard. It should be twice as many inches deep as the proportions of cement and ballast. For instance, if the cement is 1 in 8, it should be 16 inches deep. Inside, at 2 inches from the top, nail a lath all the way round; and after placing the measure at one end of the platform, fill the box with shingle or ballast to the level of the lath, and complete with cement, striking the cement level with a straight-edge. The box measure can then be lifted up and removed, when the cement will fall down over and among the aggregate, and the whole mass should be twice turned over *dry*. Water can then be added through a rose, and the whole turned twice over again. As little water should be added as possible, but enough to thoroughly moisten the whole mass. The concrete is then fit for use. In dry weather it is necessary to keep the work damp, as, if there is not sufficient water to enable the cement to set—about 11½ per cent.—the concrete will be useless. It is also important to thoroughly wet the previous work on which the fresh concrete is to be laid."

Concrete is best placed in position from barrows wheeled close up; it should then be well and solidly rammed down. To tip it from a height (as was formerly the practice) is objectionable, as tending to disintegrate the ingredients of which it is composed.

The Kind of Mortar Employed.—In the construction of brick or stone tanks, hydraulic mortar or cement mortar, either one or the other, or both, is invariably used. The following is their composition :—

Hydraulic Mortar.

	By measure.
Best blue lias lime	1 part.
Clean sharp river sand	2 parts.
or,	
Best blue lias lime	1 part.
Burnt clay	2½ parts.
or,	
Best blue lias lime	1 part.
Puzzolana	1 part.
Clean sharp sand	6 parts.

Cement Mortar.

Cement, Portland	1 part.
Clean, sharp sand	3 parts.

The lime should be fresh burnt, and not more than sufficient of the mortar for a day's work prepared at once. The cement mortar should only be made as it is being used.

The characteristics of good Portland cement are thus succinctly stated by Mr. Faija:—"In colour it should be of a dull, bluish grey; and should have a clear, sharp, almost floury feel in the hand; it should weigh from 112 lbs. to 118 lbs. per striked bushel (87 to 92 lbs. per cubic foot), and when moulded into a briquette, or small testing-block, and soaked in water for seven days, should be capable of resisting a tensile strain of from 300 to 400 lbs. per square inch. The cement should, during the process of setting, show neither expansion nor contraction."

Puddle.—For puddle, clay mixed with one-third sand, silt, or soil free from vegetable fibre, is preferable to pure clay, being firmer in texture, and less liable to crack when dry. It should be prepared outside of the trench, put in in thin layers as the wall of the tank is built, kept moistened, trodden well in with the feet, and backed up with earth carefully pounded. A cubic yard of puddle weighs about two tons.

Iron Tanks.—In cast-iron tanks the flanges of the bottom plates should always be *inside*; whilst those for the sides may be *outside*, and the plates should break joint with each other throughout.

Iron piers, or piers of brick, stone, or concrete, are erected at equal distances apart round the outside of iron tanks, for the purpose of supporting the gasholder columns or standards. If the tank is of small dimensions, the standards may be bolted to strong brackets secured to the upper tier of side plates.

Leakages of water from *iron tanks* may often be greatly reduced or altogether stopped by emptying a bushel or two of horse dung into the water contiguous to the escape. A handful of fine iron filings sprinkled lightly over the dung will be found of advantage. By this simple expedient, very heavy escapes have frequently been reduced to a mere drip within the space of a few minutes.

Dry Wells, and Inlet and Outlet Pipes.—The dry or stand pipe well is not necessarily the invariable accompaniment of a gasholder tank. Some engineers prefer to dispense with it altogether.

Many of the largest tanks are made without dry wells, the inlet and outlet pipes being of such ample diameter as to admit of their examination and repair, if need be, from the inside.

The advantage supposed to be gained by providing a dry well is the facility which it affords of access to the inlet and outlet pipes, both vertical and horizontal, in case of fracture, without disturbing the puddle or other backing of the tank wall.

In small tanks it is not unusual to form a recess in the tank wall in which the inlet and outlet pipes are placed, and are thus accessible when the tank is emptied of water. (Fig. 93.)

The inlet and outlet pipes, especially when of wrought-iron or steel, should be securely anchored or bolted down to the stone or concrete base on which they rest within the tank. If this is not done, the water, by reason of its floatation power, is liable to raise them slightly, and so disturb and cause a leakage through or past the puddle or concrete in which the horizontal portions of the pipes are embedded.

Thickness of Tank Walls.—The walls of masonry tanks (brick, stone, and concrete) are never required to resist, unsupported, the pressure of the water acting upon their sides; but are generally built under the surface level of the ground within the space of an excavation made for that purpose, and having a backing of earth carefully rammed all round them. If the upper portion of the tank is allowed to rise above the natural ground level, a supporting embankment is raised behind the projecting portion. The earth backing offers a resistance to the pressure of the water within the tank, greater than the combined weight of the wall and the cohesive nature of its component ingredients; and consequently in designing a tank wall this fact is allowed for, and a deduction made from the calculated unsupported thickness of the masonry.

In the well-known *Mémoire* by M. Arson, a translation of which, by Dr. Pole, is given in "King's Treatise" (Vol. II., p. 181 *et seq.*), the author investigates this subject with his usual ability. After some preliminary observations on the nature of the ground, and the choice and placing of material, he proceeds to a consideration of the forces and resistance in a gasholder tank of masonry, and deduces the formulæ as follows:—

As to the Pressure of the Water.

(1) $S\ D\ \frac{H^3}{6}$ = *the total force of the water.*

Then as to the threefold resistance to this force.

(1) $C\,D^1 \frac{H^2}{2}$ = *the resistance of the earth backing.*

(2) $\frac{P\,E^2\,D^1\,H}{2}$ = *the resistance of the weight of the masonry.*

(3) $K\,H^2\,E$ = *the resistance due to cohesion.*

Adding the combined resistance from the three sources together, we have—

$$C\,D^1 \frac{H^2}{2} + \frac{P\,E^2\,D^1\,H}{2} + K\,H^2\,E.$$

And to produce stability of the tank these must be greater than the effect of the pressure of the water—

$$S\,D \frac{H^3}{6}$$

where D = Internal diameter of the tank in feet.
E = Thickness of the wall (average) in feet.
D^1 = External diameter of the tank in feet.
H = Height of wall in feet.
S = Weight of a cubic foot of water.
C = Resistance of the earth backing in lbs. per sq. foot.
P = Weight of a cubic foot of the masonry.
K = Cohesive force per sq. foot.

Applying these formulæ to a tank actually constructed, let us see how they work out. Take the tank described on p. 154 :—

D = Internal diameter of tank, 122 feet.
E = Average thickness of wall, 2½ feet.
D^1 = External diameter, 127 feet.
H = Height (or depth), 24 feet.
S = Weight of a cubic foot of water, 62·5 lbs.
C = Resistance of the earth backing per sq. foot, clay and earth, say average, 1200 lbs.
P = Weight of a cubic foot of the masonry, 112 lbs.
K = Cohesive force per sq. foot, bricks in 1 Portland cement to 3 sand, mortar, 31,680 lbs.

Then—

(1) $S\,D\frac{H^3}{6} = 62{\cdot}5 \times 122\frac{24^3}{6} = 17{,}568{,}000$ = total force of the water in lbs.

(1) $C\,D^1\frac{H^2}{2} = 1200 \times 127\,\frac{24^2}{2} = 43{,}891{,}200$ = resistance of earth backing.

(2) $\frac{P\,E^2\,D^1\,H}{2} = \frac{112 \times 2{\cdot}5^2 \times 127 \times 24}{2} = 1{,}066{,}800$ = resistance of weight of masonry.

(3) $K\,H^2\,E = 31{,}680 \times 24^2 \times 2{\cdot}5 = 45{,}619{,}200$ = resistance due to cohesion.

$90{,}577{,}200$ = total resistance in lbs.

or more than five times the pressure of the water, which is an ample margin for safety.

It has already been pointed out that the walls of brick tanks, which are porous in some degree, having a backing of clay puddle behind and over the tank bottom, are placed in equilibrium by the water on both sides, and therefore do not require to be of as great a thickness as those with an internal lining of cement impermeable to water. In the latter case special care should be taken to see that the earth backing is thoroughly consolidated behind the wall, so that the pressure of the water against the tank may be transmitted thereto direct, without danger of rupture to the masonry.

When it is required to ascertain the thickness of any portion of a tank wall to resist the force of the water pressing against it, the formula as under is applicable:—

$$\frac{P\,D}{K - P} = \text{thickness in inches.}$$

Where P = the pressure of the water in lbs. per square inch.
D = the radius of the tank in inches.
K = the safe cohesive force in lbs. per square inch.

Example.—A brick and puddle tank set in Portland cement mortar is 122 feet in internal diameter and 24 feet deep to the surface of the rest stones. Required the thickness of wall immediately above footings.

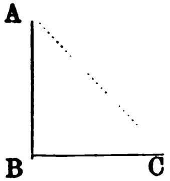
The pressure of the water on each square inch will therefore be—

$$\frac{62{\cdot}5 \times 24}{144} = 10 \text{ lbs. pressure of water per square inch.}$$

The safe cohesive strength of the brickwork in Portland cement mortar (1 cement, 3 sand) may be taken at 220 ÷ 2 = 110.

$$\text{Then: } \frac{P\,D}{K - P} = \frac{10 \times 732}{110 - 10} = \frac{7320}{100} = 74 \text{ inches, nearly, or 6 ft. 2 in.}$$

the required thickness of the wall. It will be seen, however, that in this calculation no account has been taken either of the resistance offered by the weight of the masonry, or of the support given by the earth backing; so that the result obtained is the thickness of the wall to resist the pressure of the water without any backing. And as this latter may be taken as fully equal to the other, the thickness obtained by the calculation may be reduced by one-half—*i.e.*, to 3 ft. 1 in.—which will be the required thickness of the wall above the footings. The required thickness at any other depth may be found in like manner. The pressure of the water, which varies in proportion to the depth, may be represented by a right-angled triangle A B C,



and, therefore, the thickness at the top would work out to nothing. It must not be overlooked, however, that the tank sides act as a retaining wall to the earth both during construction and at any time afterwards, when the water is withdrawn; and consequently the thickness should be graduated from the ascertained thickness at the base to about 2½ or 3 bricks width at the coping.

The thickness of 3½ feet at the base of the wall is too thin by more than one-half for an ordinary retaining wall of that height (24 feet); but it must be remembered that this apparent weakness is counterbalanced by the circular form of the structure, possessing as it does all the qualities of the arch, and being built up, both wall and backing, gradually throughout the complete circle from base to coping.

The conditions, as regards backing, of cast, wrought-iron, and steel tanks are different. These being generally erected above ground, the resistance offered to the bursting force of the contained water is entirely due to the cohesive strength of the metal.

The same formula, however, is applicable here, as will be seen from the next example of a cast-iron tank, where the safe cohesive strength of the iron is taken at 4000 lbs. per sectional square inch, its ultimate tenacity being 16,000.

Example.—A cast-iron tank is 80 feet in internal diameter and 18 feet deep. Required the thickness of the lower ring of plates. These are generally 3 to 4 feet in depth, but the water pressure on the lowest foot may be taken.

Here $\frac{62 \cdot 5 \times 18}{144} = 7 \cdot 8$ lbs. pressure of water per square inch.

Then—

$$\frac{PD}{K - P} = \frac{7 \cdot 8 \times 480}{4000 - 7 \cdot 8} = \frac{3744}{3992 \cdot 2} = \cdot 937, \text{ or say 1 inch,}$$

the required thickness; and so in like manner the required thickness of the several higher rings may be ascertained. This thickness may be slightly reduced by making allowance for the assistance given to the lower ring of plates by their attachment to the plates forming the bottom of the tank, and especially if iron hoops are employed round the outer circumference to give rigidity to the structure.

The safe cohesive strength of wrought-iron plates may be taken at 10,000 lbs. per sectional square inch.

Wrought-iron and steel tanks do not require to be strengthened by hoops.

Examples of Construction.

The following are examples of gasholder tanks constructed under moderately favourable circumstances. It will be found advisable in practice, in some instances, to increase the strength of the walls and footings. A bed of concrete should be laid round the circle, and the brick footings built upon it. This is especially necessary where the ground is of an unsatisfactory character.

BRICK TANKS.

Diameter, 21 ft. 6 in. Depth, 10 ft.

Footings, 3 single courses; width respectively, 3, $2\frac{1}{2}$, and 2 bricks.

Wall, $1\frac{1}{2}$ bricks thick for half the height, diminishing by an offset on the outside to 1 brick for the remainder.

Coping of wall, bricks set on edge, in cement.

Piers to support gasholder columns, 4 in number, brought up from foundation, and built in with the wall, each capped with a stone 2 ft. square, 8 in. thick, having 8 holes drilled in each for the holding-down bolts.

Rest or landing stones, 8 in number, 15 in. square, 6 in. thick, laid on footings built at bottom, bound in with the wall-footings.

Puddled with clay, mixed with one-third fine sand, or soil free from vegetable fibre, 2 ft. thick at bottom; and at the sides, tapering from 2 ft. at the base to one foot at the top.

Bottom, flagged with 3 in. flags.

Bricks, best hard-burnt stocks.

Mortar, lias lime one-third, sharp river sand two-thirds.

Diameter, 33 ft. 6 in. Depth, 12 ft.

Footings, 2 double courses, width 3 and 2½ bricks.

Wall, 2 bricks thick for 8 ft. high, and 1½ bricks for the remaining 4 ft., set off on outside.

Coping of wall, bricks on edge, laid in cement.

Piers, 4, bound in with wall, and brought up from foundation, each capped with a stone 2 ft. square, 9 in. thick, with 3 bolt-holes.

Rest stones, 8; each 16 in. square, 6 in. thick, let into face of wall 2 in.; laid on footings.

Puddled with clay puddle, composed of two-thirds clay and one-third fine sand, trodden well together, 2 ft. thick at bottom and sides, tapering to 1 ft. 6 in. at top.

Bottom, flagged with yard flags, 3in. thick.

Bricks, best hard-burnt stocks.

Mortar, composed of best lias lime, mixed with two-thirds sharp sand.

Diameter, 39 ft. Depth, 14 ft.

Footings, 2 double courses, 3½ bricks wide at base, diminishing by offsets to bottom of wall.

Wall, 2½ bricks at bottom to height of 6 ft.; next 4 ft., 2 bricks; remaining 3 ft. 6 in. to underneath coping, 1½ bricks thick.

Coping stones, 6 in. thick, laid in cement, and cramped together on the outside.

Piers, 5, brought up from foundation, each capped with a stone 2 ft. 6 in. square, 9 in. thick, with 4 bolt-holes.

Rest stones, 10, let 3 in. into face of wall, 18 in. square, 6 in. thick on footings.

Puddled with clay, mixed with one-third sand, 2 ft. thick at bottom and at the sides, tapering to 1 ft. 6 in. at top.

Bottom, brick paved.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sharp river sand.

Diameter, 51 ft. 6 in. Depth, 16 ft.

Footings, 2 double courses, 3½ and 3 bricks wide.

Wall, thickness at base to height of 7 ft., 2½ bricks; next 5 ft., 2 bricks; and remaining 4 ft., 1½ bricks.

Coping, bricks on edge, set in cement.

Piers, 5, carried up from foundation, each pier capped with a stone 3 ft. square, 9 in. thick, having 4 holes for holding-down bolts.

Rest stones, 10, 18 in. square, 6 in. thick, laid on footings, and let 3 in. into face of wall.

Puddled with clay, mixed with one-third sand, 2 ft. thick at bottom and sides, diminishing to 1 ft. 6 in. at top.

Bottom flagged with yard flags 3 in. thick, bedded on the puddle.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sharp river sand.

Diameter, 62 ft. Depth, 14 ft.

Footings, 4 courses; width respectively 4½, 4, 3½, and 3 bricks.

Wall, thickness at base to height of 5 ft., 2½ bricks; next 5 ft. 2 bricks; remaining 3 ft. to underneath coping, 1½ bricks.

Coping stones, 1 ft. thick, dressed to the proper radius, and laid in cement.

Piers, 6, brought up from foundation, bound in with tank wall, each capped with a stone 3 ft. square, 10 in. thick, with 4 bolt-holes.

Rest stones, 12, 18 in. square, 8 in. thick, laid on footings.

Mound or cone left in bottom of tank, 8 feet less in diameter than the latter, flagged round the base, other part pitched with random stones.

Puddled with clay two-thirds, intimately mixed with one-third sand; 2 ft. thick at bottom; the sides, 2 ft. at base to 1 ft. 6 in. at top.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sand.

Diameter, 62 ft. Depth, 20 ft.

Footings, 5 courses, first course, double, 5 bricks in width; others single; 4½, 4, and 3½ bricks wide respectively.

Wall thickness at base to height of 9 ft., 3 bricks; next 6 ft., 2½ bricks; remaining 5 ft. to underneath coping, 2 bricks.

Coping stones, 1 ft. thick, dressed to the proper radius, and laid in cement.

Piers, 8, brought up from foundation, bound in with tank wall, each capped with a stone 3 ft. square, 12 in. thick, with 4 bolt-holes.

Rest stones, 16, 2 ft. 6 in. long, 12 in. wide, 10 in. thick.

Mound or cone left in bottom of tank, 11 ft. less in diameter than the latter, covered with concrete 6 in. thick.

Puddled with clay; 18 in. thick at bottom; the sides, 2 ft. at base to 1 ft. 6 in. at top.

Bricks, best hard-burnt seconds.

Mortar, 1 Portland cement to 2 of sharp sand.

Diameter, 83 ft. 6 in. Depth, 20 ft.

Footings, 4 courses; first course, double, 5 bricks in width; others single; 4½, 4, and 3½ bricks wide respectively.

Wall, from base to height of 7 ft., 3 bricks; next 7 ft., 2½ bricks; and remaining 6 ft., 2 bricks thick.

Coping, bricks set on edge, and laid in cement.

Piers, 9, brought up from foundation, each capped with a stone 4 ft. square, 10 in. thick, with 4 holes for holding-down bolts of columns.

Rest stones, 18, 24 in. square, 10 in. thick, laid on footings, and let 3 in. into sides of tank.

Puddled with clay, 2 ft. thick at bottom; the sides, 2 ft. at base, tapering to 1 ft. 6 in. at top.

Centre pillar, to support crown of gasholder when down, 3 ft. 6 in. diam., built of brick, coated with cement.

Bottom, flagged with Yorkshire flags, 4 in. thick.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sharp river sand.

Diameter, 102 ft. Depth, 24 ft.

Footings, 6 bricks wide at base, diminishing by offsets to the bottom of wall.

Wall, thickness at base to 7 ft. in height, 4 bricks; next 7 ft., 3½ bricks; next 5 ft., 3 bricks; and remaining 4 ft. to coping, 2½ bricks thick.

Coping of stone, 1 ft. thick.

Piers, 12, carried up and built in with wall from foundation. Each capped with a stone 4 ft. square, 15 in. thick, with 4 bolt-holes.

Rest stones, 24, 2 ft. 6 in. square, 12 in. thick, let 4 in. into bottom of wall, and resting on footings.

Stones, 72 in number, 18 in. long, 12 in. by 12 in., built into tank wall, against which the channel guides are fastened.

Puddled with clay, 2 ft. thick at bottom; the sides, 2 ft. 6 in. at base, tapering to 1 ft. 6 in. at top.

Bottom, concreted over the puddle to the depth of 10 in.

Centre pillar, 4 ft. square.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sharp river sand.

Diameter, 102 ft. 6 in. Depth, 30 ft.

Footings, 1 double and 4 single courses, respectively 6, 5½, 5, 4½, and 4 bricks wide.

Wall, 3 bricks wide for 10 ft. high; next 10 ft., 2½ bricks; and remaining 9 ft. to coping, 2 bricks.

Coping of stone, 12 in. thick, not less than 4 ft. long each stone,

Strengthening rings, of brickwork, laid in cement, 5—

1st ring,	2 ft.	6 in.	from bottom,	7	bricks deep.
2nd do.	8 ,,	6 ,,	,,	6	do.
3rd do.	14 ,,	0 ,,	,,	6	do.
4th do.	19 ,,	6 ,,	,,	5	do.
5th do.	24 ,,	0 ,,	,,	4	do.

Piers, 12, brought up from foundation along with and bound into the wall, each capped with a stone 4 ft. 6 in. square, 15 in. thick, with 4 bolt-holes.

Rest stones, 24, 27 in. square, 12 in. thick, on footings, and let 4 in. into tank wall.

Puddled with clay 2 ft. thick throughout.

Centre pillar, of brick, 4 ft. square, cemented over.

Bottom concreted to the depth of 12 in. over the puddle.

Bricks, best hard-burnt stocks.

Mortar, lias lime, mixed with two-thirds sharp river sand.

Diameter, 122 ft. Depth, 24 ft.

Concrete under footings of wall and rest stones, 12 in. thick and 10 ft. wide.

Footings, 8 bricks wide at base, diminishing by 8 offsets to the bottom of the wall.

Wall, thickness at base to 8 ft. 9 in. in height, 4 bricks; next 7 ft., 3½ bricks; next 4 ft. 6 in., 3 bricks; and remaining 3 ft. to coping, 2½ bricks thick. Batter of wall 1 in 100.

Coping of stone, 9 in. thick, by 24 in. wide, and not less than 3 ft. 4 in. long.

Piers, 14, each 7 bricks square carried up and built in with wall from foundation, and capped with a stone 5 ft. 4 in. square, 18 in. thick, and with 4 holding-down bolts to each.

Rest stones, 28, 3 ft. 6 in. by 2 ft. by 12 in. thick, let into wall 4½ in., and resting on footings.

Guide rail stones, 56 in number, built into tank wall, 28 of which are 2 ft. by 1 ft. 6 in. by 1 ft. 6 in., the remaining 28 being 2 ft. 6 in. by 1 ft. 6 in. by 1 ft.

Brick ring or apron extending 6 ft. from inside of tank wall at the bottom to form a floor, 3 courses of bricks thick laid flat.

Centre pillar of brickwork, 4 ft. diam., cemented over.

Mortar, Portland cement, 1 part; sand, 3 parts.

Bricks, picked common.

Puddle behind wall of tank 24 in. thick at bottom, tapering to 18 in. at top. On cone in tank bottom 18 in. thick.

Concrete over surface of puddled cone, 6 in. thick.

Diameter, 145 ft. Depth, 55 ft.

Top of tank, 4 ft. above ground level.

Footings, 4 double courses, respectively 5 ft., 4 ft. 8 in., 4 ft. 4½ in., and 4 ft. wide.

Wall, to height of 10 ft. above footings, 3 ft. 7 in., or 4½ bricks thick; next 10 ft., 4 bricks; next 10 ft. 3½ bricks; next 15 ft., 3 bricks; next 5 ft., 2½ bricks; remaining 4 ft., exclusive of coping, 2 bricks thick.

Strengthening rings, or courses, 6 courses in every 5 ft. of height; also the 8 finishing courses, and the corresponding courses in piers, set in cement. The brickwork at no part carried higher than 5 courses of bricks, until the circle up to that level is completed, puddled, and backed up.

Coping of stone, 12 in. thick, bedded in cement.

Piers, 16, 4 ft. 8 in. wide, each capped with a stone 5 ft. square, 18 in. thick, for supporting columns; 4 holes in each for holding-down bolts; the said holding-down bolts, with cast-iron plate, built into each pier, 10 ft. below level of coping.

Rest stones, 32, let 4½ in. into face of wall, and resting on piers of brickwork forming part of the general footings.

Blocks of stone, 18 in. by 12 in. by 12 in., inserted in wall opposite each pier, for securing guides.

Cone in centre of tank, 6 ft. less in diameter at the base than the interior of tank; lower part, to height of 20 ft., paved with 4 courses of brickwork; upper part, of clay only.

Puddle, not less than 18 in. in thickness, and kept constantly well moistened; the earth being firmly pounded in behind.

Bricks, best hard-burnt stocks.

Mortar, composed of 1 part fresh burnt lias lime, to 3 parts of clean, sharp river sand; not more than sufficient for one day's work made at one time.

Cement, fresh burnt, with equal proportions of sand, mixed as it is being used.

Dry, or stand pipe well, 15 ft. diameter, 68 ft. deep, paved with 3 courses of brickwork on edge, set in cement.

Diameter, 154 ft. Depth, 40 ft. 6 in.

Foundation of concrete, 12 in. thick, 18 ft. wide under piers, and 11 ft. wide under walling.

Wall, starts from concrete foundation without footings, 5 bricks thick for a height of 16 ft. 10 in.; next 4½ bricks for 6 ft. 5 in. deep; next 4 bricks for 6 ft. 5 in.; next 3½ bricks for 6 ft. 5 in., and 3 bricks the remaining height.

Coping of stone, 12 in. by 2 ft. 3 in., in lengths not less than 4 ft. 6 in.

Piers, 16 in number, 6 ft. square from bottom to top, capped with hard Yorkshire stones, 6 ft. square and 2 ft. thick, with 4 bolt-holes in each.

Rest stones, 32, 4 ft. 10 in. by 2 ft., by 1 ft., built 4½ in. in tank wall.

Guide rail stones, 144 in number, 112 of which are 2 ft. by 1 ft. 9 in. by 1 ft., and the remaining 32 being 2 ft. by 1 ft. 9 in. by 1 ft. 6 in.

Puddled with clay 24 in. thick over surface of mound in bottom, and behind tank wall.

Brick apron, 2 ft. thick and 6 ft. wide, round bottom of tank wall inside, upon which the rest stones are set.

Centre pillar of brick, 6 ft. square at bottom and 6 ft. 8 in. square at top, capped by a stone 12 in. thick.

Mortar, Portland cement, 1 part; sand, 8 parts.

Bond, English; alternate courses of headers and stretchers throughout.

Dry well, 10 ft. in diameter, 48 ft. 6 in. deep.

Diameter, 182 ft. Depth, 40 ft.

Footings, 8 ft. deep below tank bottom, in 8 equal set-offs; placed on elm sleepers, 9 in. by 4 in.

Wall, thickness at base to 15 ft. in height, 4½ bricks; next 15 ft., 4 bricks; next 5 ft., 8 bricks, and remaining 4 ft., 2½ bricks thick.

Coping, Bramley Fall stone, 12 in. thick, and 24 in. wide.

Piers, 28, 6 ft. thick from inside tank to outside pier, and 8 ft. 9 in. wide side to side, capped with granite blocks, 5 ft. 8 in. square and 2 ft. thick, with 4 bolt-holes in each.

Rest stones, 28, built in wall 12 in., are each 4 ft. by 2 ft. 6 in. by 12 in thick.

Guide rail stones, 112 in number, 18 in. by 12 in. by 12 in.

Puddled with clay on cone in bottom of tank, under footings, and behind tank wall a uniform thickness of 24 in.

Cone at bottom covered over the clay with 9 in. of concrete, and paved with a layer of bricks on edge, set in cement.

Centre pillar of brickwork, 7 ft. 6 in. square, capped with granite block, 2 ft. thick, the whole on a foundation of concrete.

Bricks, best hard-burnt stocks.

Mortar, blue lias lime and sharp sand.

Brick ring or apron, 8 ft. thick, extending 6 ft. 6 in. from inside of tank wall at the bottom, to form a floor.

Diameter, 200 ft. Depth, 86 ft.

Footings, laid on elm boards 1½ in. thick, placed on the puddle, are 9 bricks wide at base, diminishing by 2¼ in. offsets to bottom of wall.

Wall, thickness at base to 12 ft. in height, 5 bricks; next 6 ft., 4½ bricks; next 5 ft., 4 bricks; next 5 ft., 8½ bricks; next 5 ft.,

3 bricks, and the remaining portion, 2½ bricks; being finished at top, to form a coping, with Staffordshire blue bricks set on edge in cement.

Piers, 22 in number, 5 ft. 6 in. from inside tank to outside the pier, and 7 ft. wide from side to side, surmounted by Bramley Fall column stones, 6 ft. by 5 ft. 6 in. by 1 ft. 4 in. thick, with 4 holes in each.

Piers, intermediate, 22 in number, 5 brick lengths square, brought up from bottom, and capped with stones, 2 ft. square, and 1 ft. 6 in. thick.

Rest stones, 44, 4 ft. 6 in. by 3 ft. by 1 ft. 3 in. thick, set into wall 4½ in. and bedded on concrete.

Guide rail stones, 44, 2 ft. square by 1 ft. 6 in.

Puddled with clay, over cone in centre, and under footings 2 ft. 6 in. thick, behind tank wall 2 ft. thick at bottom, tapering to 1 ft. 6 in. at top.

Concrete apron, 2 ft. thick, extending 9 ft. from tank wall all round.

Cone, covered with 6 in. of concrete over the clay puddle.

Bricks, well burnt Oldbury brown bricks.

Mortar, blue lias lime, 1 part; sand, 2½ parts.

Bond, English, alternate courses of headers and stretchers throughout.

Hoop-iron bond, every sixth course in height, 1¼ in. by 1-16th in. is inserted as follows:—In the five bricks thick part, 5 rows are laid in the thickness of the wall at equal distances apart; in the 4½ and 4 bricks thick part, 4 rows; 3½ and 3 bricks part, 3 rows; and 2 rows for the remaining height.

Shallow dry well, 12 ft. diameter, 20 ft. deep.

Diameter, 203 ft. 6 in. Depth, 38 ft.

Footings, bottom course, 7 bricks wide, 4 bricks deep, and 4 single courses, respectively 6, 5½, 5, and 4½ bricks wide.

Wall, thickness for a height of 20 ft., 4 bricks; next 9 ft., 3½ bricks; next 8 ft., 3 bricks.

Coping stone, 24 in. wide, 12 in. thick.

Strengthening rings of brickwork laid in cement, 5, divided equally throughout the depth of tank wall, 10 bricks each in depth.

Piers, 18, on foundations brought up from bottom of tank footings and bound in with wall, each capped with a stone 6 ft. square, 18 in. thick, 4 holes for bolts, the latter with plate built into pier, 10 ft. below the top of coping.

Rest stones, 36, 4 ft. square, 12 in. thick, on footings brought up from bottom of wall footings.

Puddled with clay, mixed with one-third sharp sand, and not less than 2 ft. thick in any part.

Bottom concreted over the puddle to the depth of 12 in.

Bricks, best hard-burnt stocks.

Mortar, 1 part lias lime to 2 parts sharp river sand.

Diameter, 218 ft. Depth, 44 ft. 6 in.

Foundation of concrete 2 ft. thick, 9 ft. 5 in. wide, including apron.

Wall, thickness at base to 20 ft. in height, 5 bricks; next 5 ft., 4½ bricks; next 5 ft., 4 bricks; next 5 ft., 3½ bricks; next 5 ft., 3 bricks, and the remaining portion 2½ bricks; 7 circular bands of brickwork, 6 courses deep each, and extending through the full thickness of the wall, are built in equidistantly in the height of the wall set in Portland cement mortar, the intervening portions of the wall being set in hydraulic lime mortar all in English bond.

Coping of Yorkshire stone, 2 ft. 5 in. by 6 in., in 5 ft. lengths, projecting 1 inch over wall.

Piers, 24, each 7 ft. from inside tank wall to outside of pier, and 5 ft. 6 in. wide, side to side, capped with Bramley Fall stones, 7 ft. by 5 ft. 6 in. by 2 ft., having 7 bolt-holes in each.

Piers, intermediate, 24, each 3 ft. 10 in. square, capped with stones 4 ft. by 4ft. by 6 in.

Rest blocks of concrete, 48, each 4 ft. 6 in. long by 2ft. wide, and standing 6 in. above the concrete apron.

Guide rail stones, 288, each 18 in. by 12 in. by 12 in., projecting 1 in. from face of tank wall.

Puddled with clay, not less than 18 in. at any part.

Truncated surface of cone paved with stones.

Mortar, blue lias hydraulic lime, 1 part; sand, 3 parts.

Cement mortar, Portland cement, 1 part; sand, 3 parts.

Concrete, Portland cement, 1 part; river ballast, 7 parts.

Shallow dry well, 12 ft. diameter, 26 feet deep.

COMPOSITE TANK.

Diameter, 152 ft. Depth, 31 ft.

Footings, 8 ft. 6½ in. wide at bottom, including apron, 2 ft. 6 in. thick.

Wall, brick faced, 9 in. thick, in English bond; backing of concrete; thickness at base, including the backing, to 18 ft. 9 in. high, 3 ft. 4½ in.; next 8 ft. 6 in., 3 feet thick; and the next 8 ft. 6 in., 2 ft. 8 in., to the underside of coping.

Coping of stone, 1 ft. 10 in. by 12 in., in 3 ft. lengths.

Piers, 16, are 8 ft. from inside tank wall to outside pier, and 4 ft. 6 in. wide, from side to side, formed of 9 in. brickwork on three sides, and filled in with concrete, the whole being capped with a stone 8 ft. by 4 ft. by 1 ft.

Rest stones, 2 to each pier, or a total of 32, each 4 ft. by 1 ft. 6 in. by 9 in.

Guide rail stones, 48, each 2 ft. by 1 ft. by 9 in.

Puddled with clay, 2 ft. thick throughout.

Cone, concreted over the clay puddle to a depth of 12 in. and rendered.

Centre pillar, solid brickwork, 6 ft. 6 in. in diameter at top, the sides having a batter of 1 in 40; built on a foundation of concrete 10 ft. square and 3 ft. deep. Stone cap, 6 ft. diameter by 1 ft. thick, on which is placed a double layer of 4 in. oak planking.

Hoop-iron bond, tarred and sanded, 1½ in. wide, 1-12th in. thick, is placed every 4½ ft. in height, in the proportion of 1 strip to every 4½ in. in thickness of the wall.

Mortar, Portland cement, 1 part; sand, 3 parts.

Concrete, Portland cement, 1 part; sand, 3 parts; coarse screened stones, 1½ in. diameter, 4 parts.

Dry well, 11 ft. diameter, 40 feet deep to floor.

CONCRETE TANK.

Diameter, 82 ft. Depth, 28 ft.

Wall, 8 ft. 8 in. thick at bottom, tapering on the outside to 2 ft. 4 in. at the top, built entirely of concrete, and rendered on inside with neat Portland cement ¾ in. thick.

Piers, 10, each 4 ft. by 3 ft. 8 in. of concrete.

Rest blocks of concrete 2½ ft. long, 18 in. wide, 6 in. thick.
Backing composed of sand.
Cone, concreted over surface, 18 in. thick, and rendered with neat cement ¾ in. thick.
Centre pillar, 4 ft. square, 8 ft. high.
Concrete, Portland cement, 1 part; sand, gravel, old retorts, and clinkers, 5 parts.

Diameter, 184 ft. Depth, 47 ft.
Wall, 5 ft. thick at bottom, tapering on the outside to 2 ft. 8 in. at the top, built entirely of concrete, and rendered on inside with neat Portland cement ¾ in. thick.
Piers, 20, each 8 feet thick, of concrete entirely.
Rest blocks of concrete, 6 ft. long.
Puddle, none.
Cone, concreted over surface, 12 in. thick, and rendered with neat cement ¾ in. thick.
Centre pillar, hollow, external diameter 14 ft., internal ditto, 10 ft.
Concrete, Portland cement, 1 part; gravel, sand, ballast, burnt clay, old retorts, and clinkers, 7 parts.
Dry well, 10 ft. diameter, 58 ft. deep, built of concrete 2 ft. thick, and rendered outside with neat cement.

STONE TANK.

Diameter, 89 ft. Depth, 20 ft.
Footings, 2 courses. First course composed of stones at least 8 ft. 6 in. square and 9 in. thick; second course, 8 ft. square, 9 in. thick, breaking joint at least 1 ft. on the vertical joint.
Wall, to underneath coping, built of stones not less than 16 in. on the inner face, dressed to the proper radius; no stone having less than 10 in. of a square joint, nor less than 18 in. on the bed, and 5 in. thick. Walling carried out in horizontal courses throughout the circumference of the tank, and backed up with good strong random. Two throughs to every superficial yard. Thickness of wall at base, random included, 2 ft. 8 in., gradually diminishing to 1 ft. 8 in. at top.

Coping of stones, 1 ft. 11 in. broad, 8 in. thick, and not less than 3 ft. 6 in. long, dressed to the proper radius, and laid in cement.

Piers, 9, bound in and built up along with the tank wall; a through of entire size every vertical yard, and capped with a solid cover 3 ft. 6 in. square, 15 in. thick, having 4 holes for foundation bolts of columns.

Rest or bearing stones, 18, throughs 2 ft. wide and 1 ft. thick built in along with wall footings, and projecting 1 ft. 9 in. into the tank.

Mound or Cone in bottom of tank, covered with puddle to the depth of 24 in., its base flagged with a course of yard flags 4 in. thick, the remainder pitched with dry rubble.

Pillar in centre of tank, capped with a solid stone 4 ft. square, 15 in. thick.

Mortar, lias lime, one-third; sharp clean sand, two-thirds.

CAST-IRON TANKS.

Diameter, 33 ft. Depth, 15 ft.

Plates, not more than 4 ft. in length or width. All, except top course or tier, strengthened with diagonal ribs. Lowest tier, $\frac{3}{4}$ in. thick; top tier, $\frac{1}{2}$ in. thick; intermediate and bottom plates, $\frac{5}{8}$ in. thick. Small brackets or snugs, projecting 4 in., cast $1\frac{1}{2}$ in. below centre of side plates, to support the strengthening hoops.

Flanges, 3 in. wide, with brackets between the bolt-holes.

Bolt-holes, square, $\frac{5}{8}$ in. and $\frac{1}{2}$ in., and 6 in. apart, centres.

Bolts of bottom plates and two lower tiers of sides, $\frac{5}{8}$ in.; all the others, $\frac{1}{2}$ in. square under head.

Hoops of flat wrought-iron, 3 in. by $\frac{5}{8}$ in., bound round each tier of side plates with jaws and screws.

Joints planed.

Diameter, 61 ft. Depth, 17 ft.

Plates, bottom, 1 in. thick, except outside row, $1\frac{1}{8}$ in. thick. Sides, first tier, $1\frac{1}{8}$ in.; second, 1 in.; third, $\frac{7}{8}$ in.; and fourth, $\frac{3}{4}$ in. thick. Depth, 4 ft. 3 in.; width, 4 ft. 9 in. Say, 40 plates in each tier. Snugs, projecting 4 in., cast on each plate, 2 in. below centre, to support the binding hoops.

Flanges, 8 in. wide, not less than ¾ in. thick; brackets ½ in. thick between the bolt-holes.

Bolt-holes, square, ¾ in.; 7 in. apart, centre to centre.

Bolts, ¾ in., square under head.

Hoops of flat-iron, 3½ in. by ¾ in., with suitable jaws and tightening screws bound round each tier of side plates.

Joints, planed.

Diameter, 82 ft. Depth, 20 ft.

Plates, bottom 1¼ in., except centre plate, 1½ in. Sides, first tier, 1¼ in.; second tier, 1⅛ in.; third tier, 1 in.; fourth tier, ⅞ in. 60 plates to each tier. Bearing brackets cast on each plate to support strengthening hoops.

Flanges, 4¼ in. wide, 1¼ in. thick; brackets ¾ in. between bolt-holes.

Bolt-holes, square, 1⅛ in., 5⅞ in., centre to centre.

Bolts, 1 in., square under head.

Hoops, wrought-iron, 5 in. by ¾ in., ⅝ in., and ½ in.

Joints, planed and caulked with iron cement.

Diameter, 101 ft. Depth, 22 ft. 8 in.

Plates, bottom, outside row, 1¼ in., and remainder 1 in., except centre plate, 1½ in. Sides, first and second tiers, 1¼ in.; third tier, 1⅛ in.; fourth and fifth tiers, 1 in. thick. Width, 4 ft. 2¾ in. (say 75 plates in each tier); depth, 4 ft. 6½ in. Bearing bracket, projecting 5 in., cast on each plate, 2½ in. below centre, to support the strengthening hoops.

Flanges, 3¼ in. wide, equal to plates in strength; brackets, ¾ in. between the bolt-holes.

Bolt-holes, square, 1 in.; 7 in., centre to centre.

Bolts, 1 in., square under head.

Hoops, flat-iron, 5 in. by 1¼ in., with jaws and screws, bound round each tier of side plates.

Joints, planed.

WROUGHT-IRON TANK.

Diameter, 51 ft. 4 in. Depth, 14 ft.

Plates, ⅜ in. thick, both sides and bottom, with the exception of the outer row in the latter, and those to which the guide rails are fixed up the sides, which are ½ in. thick.

Curbs, of angle-iron, extending round the entire circumference of the tank outside; top curb, 4 in. by 4 in. by ½ in.; two intermediate curbs or rings the same size, and bottom curb 4½ in. by 4½ in. by ½ in., all butt-jointed, and with lapping pieces not less than 18 in. long, riveted to the side plates of the tank with ⅝ in. rivets 6 in. apart.

Vertical stays, 12 in number, serving as guides for the holder, 14 ft. long, formed of two 3 in. by 2½ in. by ⅜ in. angle-irons placed thus: ┘└ and riveted to the ½ in. plates up the sides before mentioned with rivets 6 in. apart.

Lap of plates, not less than 1½ in., riveted hot with ⅝ in. rivets, 1½ in. centres.

Masonry standards or iron brackets to support columns.

STEEL TANKS.

Diameter, 62 ft. Depth, 18ft. 3 in.

Plates, mild steel, bottom or floor plates, $\frac{7}{16}$ in. thick. Sides, four rings, bottom ring, $\frac{7}{16}$ in., second ring, ⅜ in., and two top rows, $\frac{5}{16}$ in. except standard plates, which are ⅜ in.

Curbs, bottom curb securing sides and bottom, of angle-steel 4 in. × 4 in. × ½ in. Top curb, 3½ in. × 3½ in. × $\frac{7}{16}$ in. angle-steel.

Guides, 16 in number, 6 in. × 3 in. × 3 in. × ⅜ in. channel-steel.

Brackets of flat and angle-steel to support standards.

Lap of plates, 2½ in., ⅝ in. rivets, 2 in. centres.

Diameter, 102 ft. Depth, 20 ft. 8 in.

Plates, mild steel, bottom or floor plates, outer row, $\frac{7}{16}$ in. thick. Inner rows, ⅜ in. thick. Sides, five rings, bottom ring, ½ in. thick; next two rings, ½ in.; top rings, ⅜ in. thick.

Curbs, bottom curb securing sides and bottom, of angle-steel, 4 in. × 4 in. × ⅝ in. Top curb 3½ in. × 3½ in. × ⅝ in. angle-steel. Top of tank finished with a ½ in. steel plate riveted to standards and top curb, and curved to radius of tank.

Guide bars, 24 in number, 6 in. × 3 in. × 3 in. × ⅜ in. channel-steel.

Brackets of flat and angle-steel to support standards.

Lap of plates, 2¼ in., ¾ in. rivets, 2 in. pitch. Vertical joints to overlap 4½ inches, and to be double riveted.

ANNULAR OR RING TANKS.

Cast-Iron.

Diameter, 75 ft. Depth, 19 ft.

Plates, bottom or ring plates, 3 ft. 6 in. wide, 1 in. thick. Inner circles, 1 tier of plates only, 4 ft. deep, 1 in. thick; strengthened with 2 horizontal ribs 2 in. deep by $\frac{3}{4}$ in. thick on side next centre of tank, and on other side with 2 vertical brackets, 9 in. at bottom, diminishing to nothing at top, $\frac{3}{4}$ in. thick, with foot, 9 in. by 6 in. by $\frac{3}{4}$ in., on bottom of each bracket, Outer circle, 4 tiers, 4 ft. 9 in. deep, and 1 in., $\frac{7}{8}$ in., $\frac{3}{4}$ in., and $\frac{5}{8}$ in. thick respectively. 55 plates in the circumference. Snug, projecting $4\frac{3}{4}$ in., 2 in. below centre, to support binding hoops.

Flanges, $3\frac{3}{4}$ in. wide, equal to plates in strength, with brackets between the bolt-holes.

Bolt-holes square, $\frac{7}{8}$ in., 6 in. centre to centre.

Bolts, $\frac{7}{8}$ in. square under head.

Hoops, flat-iron, 4 in. by 1 in., with suitable jaws and screws, bound round each tier of outside plates.

Joints, $\frac{1}{2}$ in. thick, caulked with iron cement.

Diameter, 103 ft. Depth, 22 ft.

Plates, bottom or ring, 5 ft. wide, 1 in. thick. Inner circle, 1 tier of plates only 4 ft. deep, 1 in. thick; strengthened with 2 horizontal ribs, 2 in. deep by $\frac{3}{4}$ in. thick on side next centre of tank, and on other side with 2 vertical brackets, 9 in. at bottom, diminishing to nothing at top, $\frac{3}{4}$ in. thick, with foot on bottom of each, 9 in. by 6 in. by $\frac{3}{4}$ in. Outer circle, 5 tiers, 4 ft. 5 in. deep, and $1\frac{1}{4}$ in., 1 in., $\frac{7}{8}$ in., $\frac{3}{4}$ in., and $\frac{3}{4}$ in. thick respectively. 66 plates in the circumference. A snug or bearing bracket cast on each of the outside plates, $2\frac{1}{2}$ in. below centre, and projecting 4 in. for supporting the binding hoops.

Flanges, 3 in. wide, 1 in. thick, with brackets between the bolt-holes.

Bolt-holes, $\frac{3}{4}$ in. square, 6 in. apart, centre to centre.

Bolts, $\frac{3}{4}$ in., square under head.

Hoops, flat-iron, $4\frac{1}{2}$ in. by $\frac{3}{4}$ in. for bottom tier, $4\frac{1}{2}$ in. by $\frac{5}{8}$ in. for the others, with jaws and tightening screws.

Joints, $\frac{1}{2}$ in. thick, caulked with iron cement.

Diameter, 110 ft. Depth, 24 ft. 2 in.

Plates, bottom or ring, 3 ft. 10 in. wide, ¾ in. thick. Inner circle 1 tier of plates only, 4 ft. deep, ¾ in. thick; strengthened with 2 horizontal ribs, 2¼ in. broad by ¾ in. thick on side next centre of tank, and on the other side with 2 vertical brackets, 9 in. at bottom, diminishing to nothing at top, ¾ in. thick, with foot on bottom of each, 9 in. by 6 in. by ¾ in. Outer circle, 5 tiers, 4 ft. 10 in. deep, and 1¼ in., 1 in., ⅞ in., ¾ in., and ¾ in. thick respectively, 66 plates in the circumference. A bearing bracket cast on each of the outside plates, 2½ in. below centre, and projecting 4 in., for supporting the binding hoops.

Flanges, 3 in. wide, and same strength as the respective plates; brackets between the bolt-holes.

Bolt-holes, ⅞ in. square, 6 in. apart, centres.

Bolts, ⅞ in., square under head.

Hoops, flat-iron, 5 in. by ¾ in. for the bottom tier, and 4½ in. by ⅝ in. for the others, with suitable jaws and tightening screws.

Joints, ½ in. thick, caulked with iron cement.

Wrought-Iron.

Diameter, 127 ft. Depth, 20 ft. 8 in.

Annular space, 3 ft. 9 in. wide.

Plates, bottom or ring plates ½ inch thick; sides five rows deep; first and second row of plates from bottom ½ in. thick; third and fourth rows, 7-16ths in. thick, and the fifth or top row ⅜ in. thick; lap of plates, 3 in.; the top of the inner row of plates being 8 in. lower than the outer row; angle-iron curbs in bottom, 4 in. by 4 in., by ⅝ in. thick; the ½ in. and 7-16ths in. plates riveted with ⅞ in. rivets, 2½ inches apart, and the ⅜ in. plates by ¾ in. rivets, 2 in. apart.

Curbs, top outer curb of angle-iron 5 in. by 5 in. by ½ in.; top inner curb of angle-iron 3 in. by 3 in. by ½ in.; both riveted with ¾ in. rivets, 6 in. apart.

Standards, 18, box form, 15 in. by 9 in.. of ⅜ in. plates on three sides, 3 in. by 3 in. by ½ in. angle-iron to secure the same to side sheets, and extending round the bottom of the standard at its lower end, and 5 in. by 5 in. by ⅝ in. angle-iron round the top to form a base for the columns, all riveted at 6 in. apart with ¾ in. rivets. Two of these standards form the inlet and outlet

pipes, for which purpose they are continued under the annular space and up the inside of the inner ring of side sheets, and riveted with $\frac{3}{4}$ in. rivets as before, but only 2 in. apart.

THE GASHOLDER.

THE HOLDER or floating vessel (Fig. 95) is the storage reservoir for the gas, and it serves the all-important purpose of equalizing the distribution of the gas under pressure, and ensures an unbroken continuity of supply so long as any gas remains in it. In form it is invariably cylindrical like a beaker, inverted, and works freely up and down in the tank. To keep it in the true vertical position carriages are fixed on the top and bottom of the vessel, and these carry rollers which work in or against guide-rails attached to the tank sides and to the columns or standards.

The holder may be either single (Fig. 95) or telescopic (Fig. 96) in two or more lifts. When it is made in the telescopic form, its capacity is nearly double or treble or quadruple (as the case may be) the capacity of the single-lift holder for equal dimensions of tank. Ground space and capital are thus economized by its adoption.

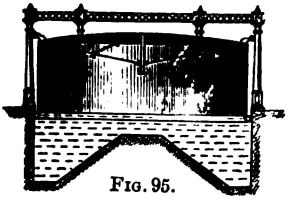


FIG. 95.

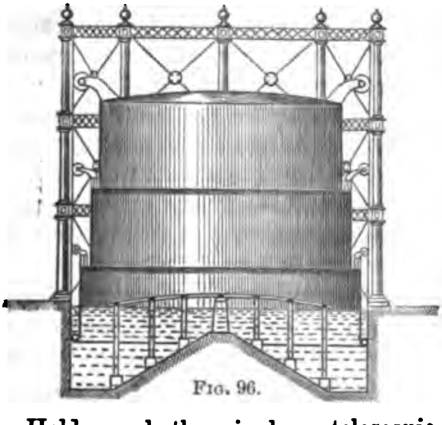


FIG. 96.

Telescopic holders require great care in construction and working—*first*, to ensure accuracy in the "cupping" of the water-lute or seal (composed of cup and grip), and, *second*, to prevent the water in the lute from freezing, which endangers the action of the vessel, or causes distortion, and imperils the lighting of the district.

Holders, whether single or telescopic, are counterbalanced or not, as is found desirable or necessary. Counterbalance weights are not

required where an exhauster on the one hand, and a governor on the other, are employed, as is the case in all but the very smallest works. In the latter, when the diameter and depth of the holder nearly approximate, it will generally be found of advantage to reduce the pressure by counterbalancing.

The crown or roof of a holder may be either trussed (Fig. 95), or untrussed (Fig. 96). In the latter case the top curb, being without radiating struts, requires to be made sufficiently strong to resist the pressure of the gas exerted on the underside of the roof which tends to distort the curb. A framework of wood or iron is required to be erected within the tank to support the untrussed roof when the holder is empty of gas, and resting on the landing stones.

The usual rise given to the roof or crown of a holder is 5 per cent. or one-twentieth of the diameter.

The trussing of a holder is in principle precisely similar to that of the roof of a building. It consists of a crown Plate with king post or centre pillar, having the main T rafters radiating therefrom to the top curb, usually angle-steel of strong section, these being braced with main and secondary tie rods and struts; secondary rafters extending from the curb to about two-thirds of the radius, and all braced together with angle or flat-steel purlins; the whole when complete somewhat resembling a spider's web. Opposite each column and intermediately, are vertical stays reaching from the top to the bottom curb and secured thereto.

The top and bottom curbs of a holder are its most important members, and should be carefully designed, both as regards th strength and form, to resist the strains to which they are subjected.

The lower guide framing of a holder consists of a series of channel-irons secured by Lewis bolts to the sides of the tank, one in a vertical line with each column or standard, and one intermediately, in which the rollers, held by carriages attached to the bottom curb, revolve. In the case of telescope holders, each outer lift also carries channel guides attached to the curbs, top and bottom, to receive the rollers of the corresponding inner lifts.

The upper guide framing may either be composed of cast-iron columns, or wrought-iron or steel standards, with back and front members braced together by lattice bars, and having a channel or tee-iron guide in front, within or upon which the guide rollers revolve. Tangential rollers are also sometimes applied to vessels of large size.

The roller carriages are attached to the top curb and roof plates (which are made thicker at these points), and, in the case of telescopic holders, to the top of the grip.

The cast-iron columns or wrought-iron or steel standards, are braced together by a series of wrought-iron or steel girders at the upper end (Fig. 95), and also intermediately in the case of telescopic holders

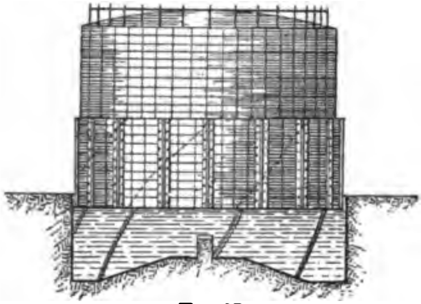


Fig. 97.

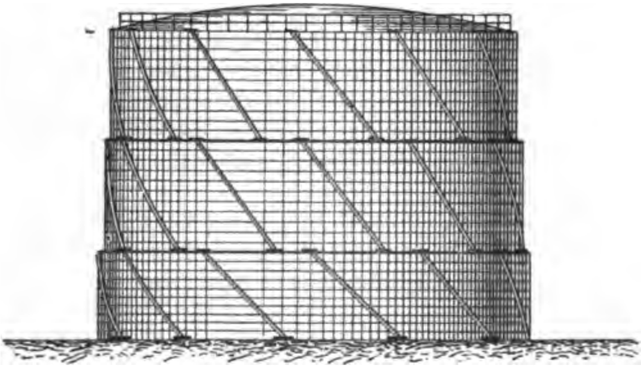


Fig. 98.

(Fig. 96). Diagonal wind ties of round wrought-iron are also employed to give rigidity to the framing when the columns or standards are of considerable height. (Fig. 96.)

Gasholders with the upper Guide-Framing either partially or wholly dispensed with.—Mr. G. Livesey first introduced at Rotherhithe the method of carrying the upper lift of a three-lift holder beyond the guide framing, the only additions made in this case being the replacing of the channel guides with H-iron to furnish paths for the

combined radial and tangential rollers on the grips of the middle and outer lifts. He has further extended this principle at East Greenwich, where the two upper lifts of the large holders rise above the guide-framing.

The invention of Mr. W. Gadd introduces a new principle of guiding; the elevated framing being entirely dispensed with, and the vessel guided from the bottom curb. The channel or rail guides, which may either be attached to the tank sides (Fig. 97), or to the outside of the holder (Fig. 98), are placed at an angle like the thread of a screw, instead of in the vertical plane. The rollers upon the bottom curb, or upon the tank coping as the case may be, are ranged either radially or tangentially with the sides of the vessel; and as they work in the channels or rails provided for them, the floating vessel rises and descends in the tank with a helical or screw-like motion.

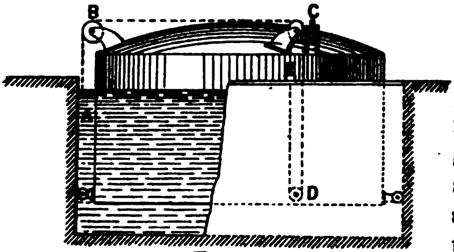


FIG. 99.

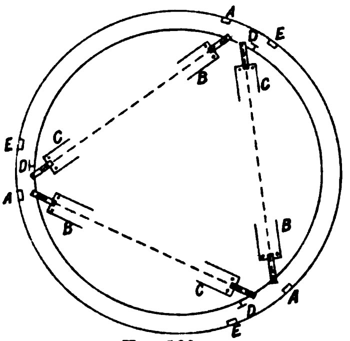


FIG. 100.

Mr. E. Lloyd Pease in his ingenious arrangement of wire ropes and pulleys also dispenses with the upper guide framing. The following diagrams (Figs. 99 and 100) shew the principle of the arrangement when adapted to a single lift holder.

As will be seen, three ropes at least are required. These are made of galvanized steel-wire, varying in size from half an inch upwards, according to the size of holder. Each rope is fastened, as shewn, to brackets A and E on the tank and passes over the pulleys B C D carried on the holder. The pulleys are grooved so that the rope cannot slip out of place, and small springs are used to keep the ropes at an even tension. The ropes act independently of each other, so that in case of a failure only one rope is affected.

Mr. G. Livesey's Hydraulic Seal (Fig. 101), for attaching to the underside of the roof of a gasholder over the inlet and outlet pipes,

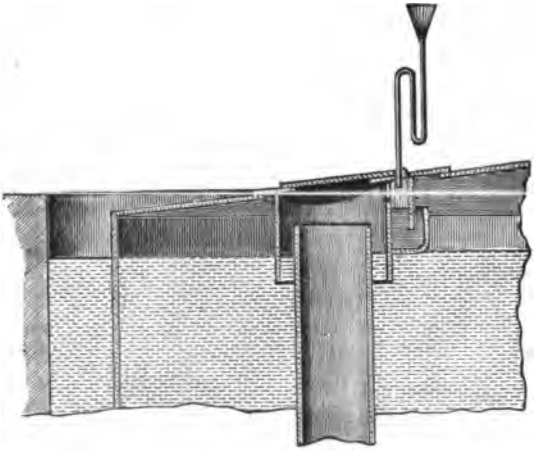


FIG. 101.

is an ingenious device for allowing access to the pipes without having to discharge the gas contained in the crown.

Precautions to be observed in the Working of Gasholders.—Telescopic holders are liable in winter to be thrown out of order by the freezing of the water in the cup between the lifts. When the lower lift is down, the upper lift in its progress downward rolls the ice and snow in the lute into lumps, often, if not removed, throwing the vessel out of plumb, and even fracturing the columns. Great care should therefore be taken to keep the water-lute clear; and where steam can be readily applied, it is of the utmost service in accomplishing this object in time of frost. Appliances of various kinds have been devised for preventing the freezing of the water in gasholder tanks and cups, by admitting steam or hot water at intervals round the circumference of the vessel.

Another important precaution is to keep the top or crown of the holder, whether single or telescope, clear of snow, especially when the latter is drifting. Nothing will sooner break down a holder and its guide framing than allowing a mass of snow to collect and lie on one side of the roof.

The oscillation of a telescope holder during strong winds is greater when uncupped than when the lifts are joined. Its liability to damage

from wind is also greater when uncupped, even although less surface is presented to the wind's action.

The sheeting of a holder, being thin and the portion most liable to wear out by oxidation, should be coated outside at least once a year with good oxide of iron or other suitable paint. All rust should be removed before laying on the paint, and for this purpose the sheets should be scrubbed with a brush made of short steel wires. For removing tar a steel scraper may be employed. If coating with tar be preferred to paint, the following recipe will be found useful:

1 gallon of tar.
½ lb. of slaked lime.
½ lb. of pitch.
½ lb. of tallow.
½ pint of coal naphtha.

Dissolve the pitch and mix the lime in the tar by heating them in a boiler, being careful not to boil them; ladle out the hot liquid into a bucket, and then add the tallow and the naphtha. Stir the mixture occasionally, and with a brush paint it on the holder before it grows cold.

It happens not unfrequently that the roof of a gasholder becomes pitted with small pin-holes from which there is a considerable and constant escape of gas. This may arise from the inferiority of the iron in the first instance; or from allowing the sheets to become oxidized before fixing; or it may be due to neglect to paint the vessel when in use. In districts where there are numerous chemical works, the impurities in the atmosphere affect the sheets in this manner. The leaks may be stopped by coating the roof with hot tar, and riddling dry sand or cement over it through a sieve, at the same time rubbing the mixture well in with a stiff brush.

TABLE OF THE WEIGHTS OF GASHOLDERS

In pounds for every One-Tenth of an Inch Maximum Pressure, and from 20 to 200 Feet in Diameter.

Diameter of Gasholder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.	Diameter of Gasholder in Feet.	Weight in lbs. for each One-tenth of an Inch Pressure.
20	164	53	1149	86	3026	119	5793
21	181	54	1193	87	3097	120	5891
22	198	55	1238	88	3168	121	5990
23	217	56	1283	89	3241	122	6089
24	236	57	1329	90	3314	123	6189
25	256	58	1376	91	3388	124	6290
26	277	59	1424	92	3463	125	6392
27	298	60	1473	93	3538	126	6495
28	321	61	1522	94	3615	127	6598
29	344	62	1573	95	3692	128	6703
30	368	63	1624	96	3770	129	6808
31	393	64	1676	97	3849	130	6914
32	419	65	1729	98	3929	131	7021
33	446	66	1782	99	4010	132	7128
34	473	67	1837	100	4091	133	7237
35	501	68	1892	101	4173	134	7346
36	530	69	1948	102	4256	135	7456
37	560	70	2005	103	4340	136	7567
38	591	71	2062	104	4425	137	7678
39	622	72	2121	105	4510	138	7791
40	655	73	2180	106	4597	139	7904
41	688	74	2240	107	4684	140	8018
42	722	75	2301	108	4772	141	8133
43	757	76	2363	109	4861	142	8249
44	792	77	2426	110	4950	143	8366
45	828	78	2489	111	5041	144	8483
46	866	79	2553	112	5132	145	8601
47	904	80	2618	113	5224	146	8720
48	943	81	2684	114	5317	147	8840
49	982	82	2751	115	5410	148	8961
50	1023	83	2818	116	5505	149	9083
51	1064	84	2887	117	5630	150	9205
52	1106	85	2956	118	5696	200	16,364

To ascertain the Weight of a Gasholder by the above Table, the Diameter and Maximum Pressure being known.

Rule.—Multiply the number of lbs. standing opposite to the diameter by the pressure in tenths of an inch.

Example.—What is the weight of a gasholder 78 feet in diameter, giving a maximum pressure of 32/10ths?

$$2489 \times 32 = 79{,}648 \text{ lbs., weight of gasholder.}$$

To ascertain, by the preceding Table, the Pressure which a Gasholder will give, the Diameter and Weight being known.

Rule.—Divide the weight in lbs. of the gasholder by the weight given opposite to the diameter.

Example.—What pressure will a gasholder give whose weight is 32,075 lbs., and diameter 56 feet?

$$32{,}075 \div 1283 = 25/10\text{ths, maximum pressure of gasholder.}$$

The figures given in the foregoing table are based on the weight of a cubic foot of water—viz., 62·5 lbs.; a column of water 1/10th of an inch high, with an area of 1 square foot, being ·52083 lbs., or the 120th part.

Thus, if the area of the holder in feet (obtained by squaring the diameter and multiplying by ·7854) be multiplied by 62·5, the weight of a cubic foot of water in lbs., and divided by 120, the number of 10ths of an inch in a foot, the product will be the weight of the holder in lbs. for each 1/10th of an inch maximum pressure.

Or thus: The area of a circle is to the square of its diameter as ·7854 is to 1; hence the weight of a gasholder in lbs., to give 1/10th of an inch pressure, is to the square of its diameter in feet as ·52083 × ·7854 is to unity; or, which is the same thing, as ·4091 is to unity. So to ascertain the weight of a holder, say, 100 feet diameter, giving a maximum pressure of 35/10ths—

$$100^2 \times 35 \times \cdot4091 = 143{,}185 \text{ lbs., weight of gasholder.}$$

TABLE

Giving the CAPACITY OF GASHOLDERS *in Cubic Feet for every Foot in Depth, and from* 20 *to* 150 *Feet in Diameter, advancing Half a Foot at a Time.*

Diameter of Holder in Ft.	Capacity in Cub. Ft. for every Foot in Depth of Holder.	Diameter of Holder in Ft.	Capacity in Cubic Ft. for every Foot in Depth of Holder.	Diameter of Holder in Ft.	Capacity in Cub. Ft. for every Foot in Depth of Holder.	Diameter of Holder in Ft.	Capacity in Cub. Ft. for every Foot in Depth of Holder.	Diameter of Holder in Ft.	Capacity in Cub. Ft. for every Foot in. Depth of Holder.
40	1256·64	62½	3067·96	84½	5607·95	106½	8908·20	128½	12968·72
40½	1288·25	63	3117·25	85	5674·51	107	8992·04	129	13069·84
41	1320·25	63½	3166·92	85½	5741·47	107½	9076·27	129½	13171·35
41½	1352·65	64	3216·99	86	5808·81	108	9160·90	130	13273·26
42	1385·44	64½	3267·46	86½	5876·55	108½	9245·92	130½	13375·55
42½	1418·62	65	3318·31	87	5944·09	109	9331·33	131	13478·24
43	1452·20	65½	3369·56	87½	6013·21	109½	9417·14	131½	13581·33
43½	1486·17	66	3421·20	88	6082·13	110	9503·34	132	13684·80
44	1520·53	66½	3473·23	88½	6151·44	110½	9589·93	132½	13788·67
44½	1555·28	67	3525·66	89	6221·15	111	9676·91	133	13892·94
45	1590·43	67½	3578·47	89½	6291·25	111½	9764·28	133½	13997·59
45½	1625·97	68	3631·68	90	6361·74	112	9852·05	134	14102·64
46	1661·90	68½	3685·29	90½	6432·62	112½	9940·21	134½	14208·08
46½	1698·23	69	3739·28	91	6503·89	113	10028·77	135	14313·91
47	1734·94	69½	3793·67	91½	6575·56	113½	10117·71	135½	14420·14
47½	1772·05	70	3848·46	92	6647·62	114	10207·05	136	14526·75
48	1809·56	70½	3903·63	92½	6720·07	114½	10296·79	136½	14633·76
48½	1847·45	71	3959·20	93	6792·92	115	10386·91	137	14741·17
49	1885·74	71½	4015·16	93½	6866·16	115½	10477·43	137½	14848·96
49½	1924·42	72	4071·51	94	6939·79	116	10568·34	138	14957·15
50	1963·50	72½	4128·25	94½	7013·81	116½	10659·64	138½	15065·73
50½	2002·96	73	4185·39	95	7088·23	117	10751·34	139	15174·71
51	2042·82	73½	4242·92	95½	7163·04	117½	10843·42	139½	15284.08
51½	2083·07	74	4300·85	96	7238·24	118	10935·90	140	15393·84
52	2123·72	74½	4359·16	96½	7313·84	118½	11028·78	140½	15503·99
52½	2164·75	75	4417·87	97	7389·82	119	11122·04	141	15614·53
53	2206·18	75½	4476·97	97½	7466·20	119½	11215·70	141½	15725·47
53½	2248·01	76	4536·47	98	7542·98	120	11309·76	142	15836·80
54	2290·22	76½	4596·35	98½	7620·14	120½	11404·20	142½	15948·52
54½	2332·83	77	4656·63	99	7697·70	121	11499·04	143	16060·64
55	2375·83	77½	4717·30	99½	7775·65	121½	11594·28	143½	16173·15
55½	2419·22	78	4778·37	100	7854·00	122	11689·89	144	16286·05
56	2463·01	78½	4839·83	100½	7932·73	122½	11785·90	144½	16399·34
56½	2507·19	79	4901·68	101	8011·86	123	11882·31	145	16513·03
57	2551·76	79½	4963·92	101½	8091·38	123½	11979·11	145½	16627·11
57½	2596·72	80	5026·56	102	8171·30	124	12076·31	146	16741·58
58	2642·08	80½	5089·58	102½	8251·60	124½	12173·89	146½	16856.45
58½	2687·83	81	5153·00	103	8332·30	125	12271·87	147	16971·70
59	2733·97	81½	5216·82	103½	8413·40	125½	12370·24	147½	17087·35
59½	2780·51	82	5281·02	104	8494·88	126	12469·01	148	17203·40
60	2827·44	82½	5345·62	104½	8576·76	126½	12568·16	148½	17319·83
60½	2874·76	83	5410·62	105	8659·03	127	12667·71	149	17436·66
61	2922·47	83½	5476·00	105½	8741·69	127½	12767·65	149½	17553·88
61½	2970·57	84	5541·78	106	8824·75	128	12867·99	150	17671·50
62	3019·07								

Gasholder Capacity.—The holder or holders should be of capacity sufficient to contain at least the 24 hours' maximum production of gas. An excess in capacity, though not absolutely necessary, is found advantageous in point of convenience and economy, where the rate of consumption is liable to fluctuations by the non-lighting of the public lamps during the hours of moonlight; and where, as in manufacturing towns and districts, the large manufactories, generally the heaviest gas consumers, being closed on Saturday nights and Sundays, the production for these two days (unless Sunday labour is partially avoided) is greatly in excess of the consumption.

There can be no doubt, also, that abundant gasholder capacity tends to convenience, and, what is of greater importance, to economy, in gas manufacture, especially when, as is now frequently the case, a setting of eight and nine through retorts, heated by one furnace, embraces as many as 16 or 18 mouthpieces. Unless the storage capacity is very ample, it is a matter of difficulty either to start or to let down so many mouthpieces at once.

DIMENSIONS OF THE PRINCIPAL MATERIALS IN GASHOLDERS IN ACTUAL WORKING.

Single Gasholder.

Diameter, 30 ft. Depth, 15 ft.
- Roof sheets, No. 17 B. wire gauge.
- Side sheets, No. 18 B. wire gauge.
- Inlet and outlet pipes, 6 in. diam.

Single Gasholder.

Diameter, 35 ft. Depth 12 ft.
- Roof sheets, No. 15 B. wire gauge.
- Side sheets, No. 16 B. wire gauge.
- Crown plate, 3 ft. 6 in. diam., $\frac{3}{8}$ thick.
- 4 main and 4 secondary bars, of 3 in. T-iron.
- Top and bottom curbs, of 3 in. angle-iron.
- 4 columns, 13 ft. 6 in. long; diam. at base, 6 in.; at top, $5\frac{1}{2}$ in.
- 4 holding-down bolts to each column, 4 ft. long, 1 in. round iron.
- Inlet and outlet pipes, 8 in. diam.

Single Gasholder.

Diameter, 40 ft. Depth, 15 ft.

Crown plate, 3 ft. 5 in. diam., $\frac{3}{8}$ in. thick.

Roof sheets, No. 14 B. wire gauge.

Side sheets, top and bottom tiers, No. 14 B. wire gauge; all the rest, No. 15 B. wire gauge.

Rivets for sheets, $\frac{1}{4}$ in. diam., 1 in. apart, centre to centre.

Rivets for top curb, $\frac{1}{2}$ in. diam., $1\frac{1}{2}$ in. apart, centre to centre.

Rivets for bottom curb, $\frac{1}{2}$ in. diam., 6 in. apart, centre to centre.

Centre-pipe of cast-iron, 6 ft. long, 4 in. diam.

Truss cup, cast-iron, 2 ft. 6 in. diam.

12 main bars, T-iron, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in.

4 vertical stays, T-iron, $3 \times 2\frac{1}{2} \times \frac{3}{8}$ in.

Top curb, angle-iron, $3 \times 3 \times \frac{3}{8}$ in.

Bottom curb, angle-iron, $3 \times 3 \times \frac{3}{8}$ in.

4 columns, 17 ft. long; diam. at base, 9 in.; diam. at top, 7 in.

8 holding-down bolts to each column, 7 ft. long each, $1\frac{1}{4}$ in. diam.

Girders of T-iron, $3 \times 4 \times \frac{1}{2}$ in., trussed.

Balance-weights, 40 cwt.; $\frac{1}{2}$ in. chains.

Inlet and outlet pipes, 8 in. diam.

Single Gasholder.

Diameter, 44 ft. 6 in. Depth, 20 ft.

Rise of crown, 1 ft. 9 in.

Crown plate, 3 ft. 6 in. diam., $\frac{3}{8}$ in. thick.

Roof sheets, inner and outer circles, No. 12 B. wire gauge; all the rest, No. 14.

Side sheets, top and bottom tiers, No. 12 B. wire gauge; the rest, No. 17.

Rivets for Nos. 12 and 14 sheets, 5-16ths in. diam.; for No. 16 sheets, $\frac{1}{4}$ in. diam.

5 main and 5 secondary bearing bars, of T-iron, $3 \times 3 \times \frac{3}{8}$ in.

5 columns, 22 ft. long, 7 in. diam. at base, $5\frac{3}{4}$ in. diam. at top; metal 11-16ths thick.

4 holding-down bolts, 16 ft. long, $1\frac{1}{4}$ in. square-iron.

Inlet and outlet pipes, 8 in. diam.

Single Gasholder.

Diameter, 50 ft. Depth 16 ft.

Rise of crown, 2 ft. 6 in.

Crown plate, 8 ft. diam., ¼ in. thick.

Roof sheets, inner and outer circles, No. 12 B. wire gauge; all the others, No. 14.

Side sheets, top and bottom tiers, No. 14 B. wire gauge; the others, No. 16.

Rivets, ¼ in. diam., 1 in. apart, centres.

Rivets for joining sheets to angle-iron, ⅜ in. diam., 1½ in. apart, centres.

Rivets for bottom curb, ½ in. diam., 9 in. apart, centres.

10 main and 10 secondary rafters, of T-iron, 3 × 3 × ⅜ in.

Top curb, of angle-iron, 3 × 3 × ⅜ in.

Bottom curb, two rings of angle-iron, 3 × 3 × ⅜ in., 6 in. apart, with flat bar of iron, 6 in. wide and ½ in. thick, between them.

Centre strut, cast-iron pipe, 9 ft. long, 6 in. external diam., ¾ in. thick; bearing flanges, 13 in. diam., 1¼ in. thick; outer rim of cup strengthened by a ring of S C and crown-iron, 2 × 1 in., shrunk on hot.

10 vertical ribs, T-iron, 3×3×⅜ in., secured to top and bottom curbs and to side sheets.

5 columns, 18 ft. long; diam. at base, 7 in.; diam. at top, 5 in.; metal, ¾ in. thick.

Suspension chains, ½ in. short link, tested to 5 tons.

Inlet and outlet pipes, 10 in. diam.

Single Gasholder.

Diameter, 50 ft. Depth, 20 ft.

Rise of crown, 12 in.

Roof sheets, No. 14 B. wire gauge.

Side sheets, No. 15 B. wire gauge.

Rivets, 1 in. apart, centres.

Top and bottom curbs, 3 in. angle-iron.

8 vertical bars.

8 columns, 26 ft. long, cast in two lengths each; 12 in. diam. at base, 6 in. diam. at top.

Inlet pipe and outlet pipes, 10 in. diam.

Single Gasholder.

Diameter, 60 ft. Depth, 17 ft.

Rise of crown, 8 ft.

Crown plate, 4 ft. diam., ½ in. thick.

Roof sheets, inner and outer circles, No. 13 B. wire gauge ; the rest, No. 14.

Side sheets, top and bottom tiers, No 14 B. wire gauge ; the rest No 15.

Top curb, 4 × 4 × 7-16th. in. angle-iron.

Bottom curb, two bars of 3 × 3 × ⅜ in. angle-iron, placed back to back, and bar of flat-iron riveted to the bottom with ⅜ in. rivets.

16 vertical bars, 2½ × 2½ × ⅜ in. T-iron, riveted to top and bottom curbs and to side sheets.

8 columns, 18 ft. long; diam. at base, 6⅜ in.; at top, 5½ in.; metal, ¾ in. thick.

Inlet and outlet pipes, 12 in. diam.

Single Gasholder.

Diameter, 60 ft. Depth, 18 ft.

Roof sheets, inner and outer circles, No. 13 B. wire gauge; the others, No. 14.

Side sheets, top and bottom tiers, No. 14 B. wire gauge; the others, No. 15.

Top curb, 4 × 4 × ⅓ in. angle-iron.

Bottom curb, formed of two bars of angle-iron, 4 × 4 × ½ in., riveted back to back with ½ in. rivets 12 in. apart, centres.

14 vertical bars, 4 × 3 × ½ in. T-iron.

7 columns, 19 ft. 6 in. long each.

Inlet and outlet pipes, 12 in. diam.

Single Gasholder.

Diameter, 81 ft. 8 in. Depth, 20 ft. 6 in.

Rise of crown, 3 ft.

Crown plate, 4 ft. diam., ½ in. thick.

Roof sheets, inner and outer circles, No. 10; all the rest, No. 14 B. wire gauge.

Side sheets, top and bottom tiers, No. 14; all the rest, No. 16 B. wire gauge.

Rivets, ½ in. diam., 1 in. apart, centres.
16 main rafters, 5 × 3 × ½ in. T-iron.
16 secondary rafters, 4 × ½ in. flat-iron, placed on edge.
Centre strut, cast-iron pipe, 9 ft. long, 7 in. external diam., 1 in. thick; flanges, 18 in. diam., 1¼ in. thick; cup strengthened by a hoop 2 × 1 in. S C iron, shrunk on hot.
Tension rods, long Queen bolts, short Queen bolts, long suspenders, short suspenders, 16 in number each, of 1¼ in., 1½ in., 1¼ in., 1 in., and ⅞ in. round-iron respectively.
Top curb, of angle-iron, 4 × 4 × ½ in.
Bottom curb, of angle-iron, 4 × 4 × ½ in., with bar of flat-iron, 6 × ½ in. between, and riveted with ⅝ in. rivets, 12 in. apart.
12 vertical bars, 4 × 3 × ½ in. T-iron.
Inlet and outlet pipes, 14 in. diam.

Single Gasholder.

Diameter, 87 ft. Depth, 20 ft.
Rise of crown, 4 ft.
2 crown plates, 4 ft. diam., ½ in. thick.
Roof sheets, inner and outer circles, No. 12; the rest, No. 14 B. wire gauge, except 9 sheets upon which the sliding carriages are fixed, No. 7 B. wire gauge.
Side sheets, top and bottom tiers, No. 12; all the remainder, No. 14 B. wire gauge.
Rivets, 5-16ths in diam., 1 in. apart, centres.
Centre-pipe of wrought-iron, 12 ft. long, 12 in. diam.
Truss cup, wrought-iron, 3 ft. diam., ¾ in. thick.
18 main bars, T-iron, 4 × 3 × ½ in.
18 secondary bars, T-iron, 3 × 3 × ½ in.
9 rings or purlins of bracket bars, the middle purlin of angle-iron 3½ × 3½ × ½ in., the remainder of flat-iron 2 × ½ in., secured to main and secondary bars with ⅝ in. bolts.
18 principal tension rods, 1¼ in. diam.
36 diagonal tension rods, ⅞ in. diam.
36 truss bars; 18 of 1½ in. diam., 18 of 1¼ in. diam.
Top curb, 2 rings of angle-iron, 3½ × 3½ × ⅜ in.
Bottom curb, 2 rings of angle-iron, 3½ × 3½ × ⅜ in.
18 vertical truss bars, T-iron, 3½ × 3½ × ½ in.

9 columns, 22 ft. long each, 14 in. diam. at base, 11 in. at top.
4 holding-down bolts, 8 ft. long, 1½ in. diam.
Inlet and outlet pipes, 16 in. diam.

Single Gasholder.

Diameter, 100 ft. Depth, 20 ft.
Rise of crown, 5 ft.
2 crown plates, 5 ft. diam., ⅝ in. thick.
Roof sheets, inner and outer circles, No. 10; the remainder, No. 12 B. wire gauge, except carriage sheets, ¼ in. thick.
Side sheets, top and bottom tiers, No. 9; the remainder, No. 12 B. wire gauge.
Rivets, 5-16ths in. diam., 1 in. apart, centres.
Centre-pipe of wrought-iron, 14 ft. long, 24 in. diam., 5-16ths in. thick.
18 main and 18 secondary bars,
Top curb, 2 rings of angle-iron, 4 × 4 × 7-16ths in.
Bottom curb, 2 rings of angle-iron, 4 × 4 × 7-16ths in., and a flat bar of wrought-iron, 6 × ⅜ in.
18 vertical bars, T-iron, 4 × 4 × ⅜ in.
9 columns, 24 ft. long, 24 in. diam. at base, 18 in. diam. at top, 1¼ to 1 in. metals.
4 holding-down bolts, 8 feet long, 1½ in. diam.
Inlet and outlet pipes, 18 in. diam.

Single Gasholder.

Diameter, 110 ft. Depth, 26 ft.
Rise of crown, 5 ft. 6 in.
Crown plates, 4 ft. diam.; ⅜ in. thick.
Roof sheets, row next centre and outer row next curb, ¼ in. thick; second row from centre, ⅛ in. thick; and second row next curb, 3-16ths in. thick; the remainder, No. 12 B. wire gauge.
Side sheets, top and bottom rows, ½ in. thick; next row to each, 3-16ths in. thick; the remainder, No. 12 B. wire gauge.
Rivets, ¼ in. and 3-16ths in. plates, ⅜ in. rivets, 2 in. centres; the ⅛ in. and No. 12 B. wire gauge sheets 5-16ths in. rivets, 1½ in. centres; ¼ in. plates and curb ⅝ in. rivets, 2 in. centres.
Top curb of 2 angle-irons 5 × 4 × ½ in.
Bottom curb of 2 angle-irons 4 × 4 × ½ in.

Vertical stays, 14, of 2 angle-irons 3 × 3 × ½ in., and a piece of timber 12 in. × 4 in. bolted between.

Centre pipe of ½ in. plate, 2 ft. diam.

Main rafters, 28, of T-iron 5 × 3 × ½ in.

Purlins, of T-iron 3 × 4 × ½ in., and remainder of angle-iron 3 × 3 × ⅜ in.

Struts, 3, on main rafters 1½ and 1¼ in. diam.

Tie rod, principal 1⅝ in. diam., second 1½ in. diam., and third 1 in. diam.

Columns, 14, of cast-iron 1 ft. 6 in. in diam. at bottom, 1 ft. 2 in. at top; metal ⅞ in. at bottom, diminishing to ⅝ in. thick at top.

Holding-down bolts, 4, 1½ in. diam., 20 ft. long.

Lattice girders, 14, 1 ft. 6 in. deep, of two frames of angle-iron, 3 × 3 × ½ in., and braces 2½ × ½ inch riveted between, top and bottom of girder covered with a plate 10 in. wide by ⅝ in. thick.

Inlet and outlet pipes, 20 in. diam.

Single Gasholder.

Diameter, 142 ft. Depth, 55 ft.

Roof, without trussing or framework.

Roof sheets, first, or outside circle, 3 ft. long, ⅜ in. thick; rivets ⅝ in. diam., 2½ in. apart, centres. Second circle, 3 ft. long, ¼ in. thick; rivets, 9-16ths in diam., 2½ in. apart, centres; centre sheets, forming a circle, 30 ft. diam., ¼ inch thick, butted and riveted to each other by lapping pieces, 3½ in. wide; rivets 9-16ths in. diam.; remainder of roof sheets, 5 ft. long, 3-16ths in. (No. 7 B. wire gauge) thick; rivets, ⅜ in. diam., 1¼ in. apart, centres.

Side sheets, top and bottom tiers, ¼ in. thick; rivets, ½ in. diam., 1½ in. apart, centres. Intervening side sheets, No. 10 B. wire gauge; rivets, ⅜ in. diam., 1¼ in. apart, centres.

Top curb, a circular chamber or girder, in section nearly rectangular, outer depth, 18 in.; inner depth, 19¼ in.; width, 2 ft. 6 in.; constructed of 4 × 4 × ½ in. angle-iron.

Bottom curb, formed of two circles of ⅜ in. boiler plates, 12 in. wide, each riveted to a circle of angle-iron, 4 × 4 × ½ in.

32 vertical stays, three sides of a rectangular figure, 12 in. wide, 10 in. deep; formed of 4 angle-irons 3 × 3 × ⅜ in. and ¼ in. boiler-plate.

16 columns, diam. at base, 3 ft.; at top, 2 ft. 3 in.; metal, ⅞ in. to ⅝ in. thick.

4 holding-down bolts, 10 ft. long, 2¼ in. round-iron.

Inlet and outlet pipes, 30 in. diam.

Two-lift Telescopic Gasholder.

Diameter of outer lift, 44½ ft. Depth, 16 ft.

Diameter of inner lift, 43 ft. Depth, 16 ft.

Rise of crown, 1 ft. 9 in.

Crown plate, 3 ft. 6 in. diam., ⅜ in. thick.

Roof sheets, inner and outer circles, No. 12; all the rest, No. 14 B. wire gauge.

Side sheets in both lifts, top and bottom tiers, No. 12; all the rest No. 16 B. wire gauge.

Rivets for Nos. 12 and 14 sheets, 5-16ths in. diam.; for No. 16 sheets, ¼ in. diam.

Cup, inner lift, formed by 2 rings of 2½ × 2½ × 5-16ths in. angle-iron, connected together with No. 8 plates, with side of No. 10 plate, and a ring 1¼ × ½ in. half-round iron, riveted round.

Grip, outer lift, the counterpart of the cup inverted.

Main-bearing bars, T-iron, 3 × 3 × ½ in.

Secondary bearing bars, T-iron, 3 × 3 × ⅜ in.

6 vertical bars, inner lift, T-iron, 2½ × 2½ × ⅜ in.

6 vertical bars, outer lift, T-iron, 2½ × 1½ × ⅜ in.

Bottom curb, angle-iron, double, 3 × 3 × ⅜ in.

6 columns, 12 in. diam. at base, 10 in. at top; metal, 1 in. to ¾ in. thick.

Inlet and outlet pipes, 10 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 87 ft. Depth, 20 ft.

Diameter, inner lift, 85 ft. Depth, 20½ ft.

Rise of crown, 4 ft.

2 crown plates, 4 ft. diam., ½ in. thick.

Roof sheets, inner and outer circles, No. 12; the rest, No. 14 B. wire gauge, except 9 sheets upon which the carriages are fixed, No. 7 B. wire gauge.

Side sheets, top and bottom tiers, both lifts, No. 12; all the rest, No. 14 B. wire gauge.
Rivets, 5-16ths in. diam., 1 in. apart, centres.
Hydraulic cup and dip, 7 in. wide, 16 in. deep.
Centre-pipe of wrought-iron, 12 ft. long, 12 in. diam.
Truss cup, wrought-iron, 3 ft. diam., $\frac{3}{4}$ in. thick.
18 main bars, T-iron, 4 × 3 × $\frac{1}{2}$ in.
18 secondary bars, T-iron, 3 × 3 × $\frac{1}{2}$ in.
9 rings or purlins of bracket bars, the middle purlin of angle-iron, $3\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{1}{2}$ in., the remainder of flat-iron, 2 × $\frac{1}{2}$ in., secured to main and secondary bars with $\frac{5}{8}$ in. bolts.
18 principal tension rods, $1\frac{1}{4}$ in., diam.
36 diagonal tension rods, $\frac{7}{8}$ in. diam.
36 truss bars; 18 of $1\frac{1}{2}$ in. diam., 18 of $1\frac{1}{4}$ in. diam.
Bottom curb, 2 rings of angle-iron, $3\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{3}{8}$ in.
18 vertical truss bars, T-iron, $3\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{1}{2}$ in.
9 columns, 41 ft. long, 30 in. diam. at base, 20 in. at top, $1\frac{1}{8}$ to $\frac{7}{8}$ in. metal, cast in 4 lengths.
4 holding-down bolts, 8 ft. long, $1\frac{1}{2}$ in. diam.
Inlet and outlet pipes, 18 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 100 ft. Depth, 22 ft.
Diameter, inner lift, 98 ft. Depth, 22 ft.

Roof sheets, No. 11 B. wire gauge.
Side sheets, top tier, to be No. 11; all the others No. 12 B. wire gauge.
Rivets, $\frac{1}{4}$ in. diam., 1 in. apart, centres.
Hydraulic joint, 8 in. wide, 15 in. deep, No. 10 B. wire gauge; top edge of cup and bottom each of dip bound by half-round iron 2 × 1 in. thick.
Bottom curb, angle-iron, 4 × 1 in. at the root, and ring of bar-iron 4 × 1 in.
12 columns, 24 in. diam. at base, 16 in. at top; metal $1\frac{1}{8}$ to 1 in. thick.
4 holding-down bolts, 10 ft. long, 2 in. square-iron.
Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 102 ft. Depth, 22 ft.
Diameter, inner lift, 100 ft. Depth, $22\frac{1}{2}$ ft.

Rise of crown, 4 ft.

Crown plate, 5 ft. diam., $\frac{5}{8}$ in. thick.

Roof sheets, first ring next centre, No. 9; next and outer rings, No. 11; all the rest, No. 12 B. wire gauge.

Side sheets, outer lift, top and bottom tiers, No. 11; all the rest, No. 13 B. wire gauge. Inner lift, top and bottom tiers, No. 13; all the rest, No. 17 B. wire gauge.

Cup and grip, 8 in. wide, 15 in. deep, of angle-iron 3 × 3 × $\frac{3}{8}$ in.; plate, No. 7 B. wire gauge; edges stiffened with $1\frac{1}{2}$ × $\frac{3}{4}$ in. half-round-iron; $\frac{1}{2}$ in. rivets, 6 in. apart.

10 columns, 18 in. diam. at base, 14 in. at top; metal $1\frac{1}{4}$ to $\frac{3}{4}$ in. thick, cast in 4 lengths.

4 holding-down bolts, 8 ft. long, 2 in. square wrought-iron.

Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 112 ft. Depth, 26 ft.
Diameter, inner lift, 110 ft. Depth, 26 ft.

Rise of crown, 6 ft.

Roof, trussed.

Roof sheets, centre plate $\frac{1}{2}$ in. thick, next row $\frac{1}{4}$ in., next, 3-16ths in.; outer row, $\frac{1}{4}$ in.; next, 3-16ths in.; and the intermediate 7 rows, $\frac{1}{8}$ in. thick.

Side sheets, 3-16ths in. thick top and bottom rows; remainder, No. 12 B. wire gauge; the cup, 8 in. × 18 in., is formed of 2 rings of 3 × 3 × $\frac{3}{8}$ in. angle-iron, bottom and sides being $\frac{1}{4}$ in. plate, having 2 × 1 in. half-round bead at edge of plate.

Top curb, of two rings of angle-iron 5 × $3\frac{1}{2}$ × $\frac{1}{2}$ in.

Bottom curb, of 2 rings angle-iron 5 × 3 × $\frac{1}{2}$ in. placed 9 in. apart, between which bottom roller carriages are secured.

Vertical stays, inner lift, 28, 14 of which are of 2 angle-irons 3 × 3 × $\frac{1}{2}$ in. riveted on each side to a web plate 9 in. wide and $\frac{1}{4}$ in. thick; the remaining 14 being of T-iron 5 × $3\frac{1}{2}$ in. trussed with three struts and a tie rod. Outer lift has 28 vertical stays of $\frac{3}{8}$ in. guard-iron 5 in. wide, against which the guide pieces on the cup slide.

Centre column, 17 ft. 6 in. long and 2 ft. diam. of wrought-iron plates ⅜ in. thick, ¾ in. rivets, 2½ in. pitch; this is secured to the under crown plate, which is 4 ft. in diam., by a ring of angle-iron 5 × 4 × ½ in. and ¾ in. rivets; at the lower end of the column are 2 rings of angle-iron, 5 × 4 × ¾ in., placed 3½ in. apart to form a jaw to receive ends of tension rods.

Main rafters, 14, of T-iron, 4 × 5 × ½ in., trussed with six wrought-iron struts 1¼, 1½, and 1¾ in. diam., and a 1½ in. diam. tension rod. Fourteen main tie rods of 1¾ in. round-iron, extending from curb to bottom of centre column, and suspended in two places from the main rafters with ½ in. round rods; the main tie rods and the tension rods have each a wrought-iron coupling box with right and left hand threads.

Secondary rafters, 14, T-iron, 3 × 5 × ½ in., trussed as above, with four struts 1¼ and 1½ in. diam., tension rod 1¼ in diam. with coupling box; these rafters extend from curb to within 21 ft. of the centre of holder, the inner ends being secured to a main brace bar or purlin,

Purlins, 7 rows between side and centre. The main purlin mentioned above is 4½ × 4½ × 9-16ths in.; the one next curb, 4 × 3 × ½ in.; and the remainder, 3 × 3 × ⅜ in., all of T-iron.

Columns, 14, of cast-iron, 2 ft. 6 in. diameter at bottom, 2 ft. at top, and 55 ft. 8 in. high, surmounted with a large ball 30 in. diam., with spiked finial.

Girders, 2 rows, each 2 ft. deep, and 10 in. wide, of 4 angle-irons 3 × 3 × ⅜ in., with plate 10 × ⅜ in. top and bottom diagonal braces 3 × ⅜ in., at the intersection of which is a cast-iron spiked ball in two halves, 17 in. diam. across spikes.

Holding-down bolts, 4, 2 in. diam., 11 ft. 6 in. long.

Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 120 ft. Depth, 24 ft.

Diameter, inner lift, 118 ft. Depth, 24 ft.

Rise of crown, 6 ft.

Roof, untrussed, resting when down on timber framing in tank.

Roof sheets, first or outside rows, $\frac{3}{8}$ in. thick; second row, $\frac{1}{4}$ in. third row, 3-16ths in.; fourth row, No. 8 B. wire gauge; crown plates, $\frac{1}{4}$ in. thick and 6 ft. in diam.; inside row, next crown plate, 3-16ths in.; next, No. 8 B. wire gauge; and the remaining 10 rows of intermediate sheets, No. 11 B. wire gauge.

Side sheets, inner lift, 12 courses high; top and bottom course, $\frac{1}{4}$ in. thick; second course at top, 3-16ths in.; and the remainder, No. 12 B. wire gauge.

Side sheets, outer lift, 12 courses high; top and bottom course, $\frac{1}{4}$ in. thick; second course at bottom, 3-16ths in.; and the remainder, No. 12 B. wire gauge. The thicker sheets in both inner and outer lift, riveted together with $\frac{3}{8}$ in. rivets, $1\frac{1}{4}$ in. apart centres, and the others with 5-16ths in. rivets, $1\frac{1}{8}$ in. apart, centres.

Top curb, of 2 angle-irons, one at junction of roof with side sheets, $5 \times 5 \times \frac{5}{8}$ in., and the other at the inner edge of outer row of sheets, $4 \times 4 \times \frac{1}{2}$ in.; the two stiffened by gusset-pieces springing from the vertical stays.

Bottom curb, of two $5 \times 4 \times \frac{5}{8}$ in.; angle-irons, riveted to the outside of the lower row of sheets, with $\frac{3}{8}$ in. rivets, 6 in. apart. Between these two curbs, which are placed 2 in. apart, are fixed the 28 guide carriages and rollers.

Cup and grip formed of rolled channel-iron $8 \times 3\frac{1}{2} \times \frac{1}{2}$ in. riveted to the side sheets and rising and dip plates, with $\frac{1}{2}$ in. rivets 4 in. apart. A half-round bead $2 \times \frac{5}{8}$ in. being riveted to edge of rising plates, which are $\frac{3}{8}$ in. thick and 18 in. deep.

Vertical stays, 28, formed of two $4 \times 4 \times \frac{1}{2}$ in. angle-irons and a web-plate between, $\frac{3}{8}$ in. thick and 9 in. wide, secured with $\frac{3}{8}$ in. rivets, 6 in. apart; at the upper end of these is attached a gusset-plate with angle-iron edges $3 \times 3 \times \frac{3}{8}$ in., extending to the inner angle-iron curb of roof, to which and the outer curb it is riveted.

Standards 14, in the form of the letter T, 4 ft. 2 in. $\times$ 3 ft. at bottom, tapering to 1 ft. 9 in. each way at the top; each standard 51 ft. high. Between the angle-iron framework of the standards is cast-iron trellis work, 1 in. thick, on one of its sides, and wrought-iron lattice work on the other; the standards are secured to cast-iron hollow base plates 6 in. deep; 4 holding-down bolts to each standard, 11 ft. 6 in. long, $2\frac{1}{4}$ in. diam.

Lattice girders, 2 rows in the height; first or lower row, 27 in. deep; top row, 30 in. deep; formed of 4 angle-irons, 3 × 3 × ½ in. wrought-iron tension bars, 3 × ½ in., and cast-iron struts.

Inlet and outlet pipes, 24 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 151 ft. 6 in. Depth, 40 ft.

Diameter, inner lift, 149 ft. Depth, 40 ft. 3 in.

Crown trussed, rise 8 ft.

Roof sheets, outer row, 5-16ths in.; next row, 3-16ths in.; and the remainder No. 10 B. wire gauge, two centre plates ¾ in. thick and 4 ft. 6 in. diam.

Side sheets, top and bottom rows in both lifts ¼ in. thick, the remainder No. 11 B. wire gauge, ¼ in. rivets, 1 in. centre; cup and grip 10 in. wide and 20 in. deep, Piggot's form; plates ⅜ in. thick, strengthened at edges with bead-iron.

Top curb, of 2 rings of angle-iron 5 × 5 × ½ in., placed one above the other; the lower one is secured to a flat bar 10 in. wide and ½ in. thick, which is again connected by straps 4 in. wide and ½ in. thick to the top row of sheets.

Bottom curb, of 2 rings of angle-iron 5 × 4 × ⅝ in. riveted to the outside of the bottom of row of sheets with ⅝ in. rivets. Between these two rings are fixed the bottom guide roller carriages.

Vertical stays, 32 in top lift of H-iron 12 in. deep, and 32 in bottom lift, of channel-iron 8 × 2½ × ½ in., attached to sheets, cups, and curbs with ⅝ in. bolts in upper lift, and ⅝ in. screwed pins in lower lift.

Centre column, 3 ft. 6 in. diam., 22 ft. long, of plates 7-16ths in. thick.

Roof framing, 24 main radial T-iron bars 6 × 4 × ½ in. curved to roof, each with a main tension rod 2 in. in diameter át curb, and reduced to 1½ in. at the foot of centre column, and having a coupling box with right and left hand threads, 4 struts and 4 tension rods form the bracing to each main bar, the former of cross-iron 4 × 4½ × ½ in. placed vertically, and the latter of 1, 1⅛, 1¼, and 1⅜ in. round iron placed diagonally, the strongest section being nearest the centre column; 48 secondary radial

bars of 4 × ½ in. flat-iron, that is, 2 equidistant between the main radial bars, and extending from top curb towards centre a distance of 26 ft., and then for a further distance of 16 ft., in direction of the centre, another bar of the same dimensions is fixed. 17 rings or rows of purlins, divided equally from curb to centre, are fixed between main and secondary bars; the first row from centre being of 6 × ½ in. flat-iron; next 4 rows of angle-iron, 1½ × 1½ × ¼ in.; next row of angle-iron 2 × 2 × ¼ in.; next row of T-iron 3 × 6 × ½ in.; next 2 rows, which are subdivided in length by the secondary radial bars above mentioned, are of angle-iron 1½ × 1½ × ¼ in.; next row extending from main bar to main bar is of I-iron 3 × 6 × ½ in.; next two rows are divided in 3 lengths between main bars by the two secondary bars, and are of 1½ × 1½ × ¼ in. angle-iron; next row extending from main to main is of T-iron, 4 × 6 × ½ in.; next row divided in 3 lengths as before of 1½ × 1½ × ¼ in. angle-iron, and the remaining 2 rows divided in 3 as before of 2 × 2 × ¼ in. angle-iron; 3 bars of flat-iron 2½ × ⅜ in. cross diagonally in each bay formed by the two main bars.

Columns, 16, of cast-iron, 83 ft. high, 3 ft. in diam. at base, and 2 ft. 8 in. at top, metal 1 in. thick; cast-iron channel guide up the column, 5 × 3 in. inside measure, weighing 56 lbs. per foot.

Girders, 16, at top 4 ft. deep, 7 in. wide, of 4 angle-irons 3 × 3 × ⅜ in. and a top and bottom plate 7 in. wide by ⅜ in. thick; diagonal brace bars 4 × ⅜ in.; 16 intermediate girders 3 ft. 6 in. deep, 6 in. wide, of 4 angle-irons 2½ × 2½ × ⅜ in., and top and bottom plates 6 in. wide by ⅜ in. thick, diagonal brace bars 3 × ⅜ in.; at the intersection of the brace bars a cast-iron star 12 in. in diam. is riveted.

Holding-down bolts, 4, 2 in. square and 14 ft. long.

Capacity, 1,400,000 cubic feet.

Inlet and outlet pipes 30 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 197 ft. 6 in. Depth, 36 ft.

Diameter, inner lift, 195 ft. Depth, 36 ft.

Crown, untrussed, rise 10 ft.

Roof sheets, centre plate ¼ in. thick, 6 ft. diameter; row next centre of No. 7 B. wire gauge; row next curb, ½ in. thick; next row, 5-16ths in. thick; third row, No. 7 B. wire gauge, and the remaining rows of No. 11 B. wire gauge.

Side sheets, of inner lift in 18 rows; top row, ½ in.; bottom row forming cup, ⅜ in.; second row from top and bottom, ¼ in.; third row from top and bottom of No. 7 B. wire gauge; and the 12 intermediate rows of sheets of No. 11 B. wire gauge in thickness. Those of outer lift in 18 rows; top row forming cup, ¼ in.; bottom row, 5-16ths in.; second from top, No. 9 B. wire gauge; second from bottom, 3-16ths in.; third from bottom, No. 9 B. wire gauge, and the 13 intermediate rows of No. 11 B. wire gauge in thickness.

Cup and grip, 10 in. wide, 18 in. deep, of channel-iron, 10 × 3½ × ½ in., rising and dip plates, ⅜ in. thick, with 2½ × ¾ in. bead riveted to edges.

Top curb, of 2 angle-iron rings, outer one 6 × 6 × ¾ in.; inner one, 5 × 5 × ⅝ in., both double riveted to top and side sheets, with ¾ in. rivets, 2 in. apart centre to centre.

Bottom curb, of 2 angle-iron rings, 6 × 5 × ⅝ in., riveted to side sheets, with ⅝ in. rivets, 6 in. apart.

Vertical stays, 44, in upper lift of H-iron, 8 × 5 × 5 × 7-16ths in. secured to top and bottom rows of sheets and the outer angle-iron curb, but not to the intermediate sheets, except just at the centre, where there are two clips, 6 in. wide × 5-16ths in. thick, to which the sheet is riveted. Gusset pieces, 44, of 2 angle-iron frames, 2½ × 2½ × ⅜ in., riveted to a 7-16ths in. web-plate placed between them and riveted together, and to the vertical stays, outer row of top sheets, and inner angle-iron curb with ⅝ in. rivets, 4 in. pitch. Vertical stays in lower or outer lift, 44, of channel-iron, 8 × 2½ × ½ in., riveted to bottom curb, and to the sheets half way up, with four ¾ in. rivets, countersunk heads in the channel, and bolted to the channel-iron of grip with two ⅞ in. bolts.

Guide wheels, 22, at top lift of malleable cast-iron, 24 in. diameter, with steel axles or pins, mounted on wrought-iron carriages, 44 fixed under cup of upper lift, 22 on grip, and 44 on bottom curb of outer lift, all of malleable cast-iron, having steel pins and wrought-iron carriages.

Columns, 22, of cast-iron, 3 ft. diameter at bottom, and 2 ft. 6 in. at top, mounted on ornamental base 4 ft. square and 9 ft. 9 in. high, two entablatures and ornamental cap; 4 holding-down bolts to each column, $2\frac{1}{4}$ in. diameter.

Girders, upper tier, 3 ft. 6 in. deep; lower tier, 3 ft. deep, of two frames of angle-iron, 4 × 4 × 7-16ths in., with lattice bars, 4 × $\frac{5}{8}$ in. riveted between them; the top, bottom, and ends of girders covered with a $\frac{3}{8}$ in. plate 9 in. wide; rivets, $\frac{3}{4}$ in., 4 in. apart centres; at the intersection of the diagonal braces with each other are fixed plates, 12 in. diameter and $\frac{3}{8}$ in. thick.

Quality of iron, plate, angle, and T-iron of best South Staffordshire brands, the channel and H-iron of the best Belgian; the sheets of the very best South Staffordshire, equal to B. B. H. best.

Rivets, all sizes, of the best soft charcoal-iron. Those for the No. 11 B. wire gauge sheets, of No. 3 B. wire gauge in diameter and 1 in. pitch; and those for No. 7 B. wire gauge sheets, with $\frac{3}{8}$ in. rivets $1\frac{1}{4}$ in. apart centres.

Capacity, 2 million cubic feet.

Inlet and outlet pipes, 30 in. diam.

Two-lift Telescopic Gasholder.

Diameter, outer lift, 200 ft. Depth, 25 ft. 8 in.

Diameter, inner lift, 198 ft. Depth, 25 ft. 9 in.

Roof untrussed, and flat.

Roof sheets, centre plate $\frac{3}{4}$ in., row next centre plate $\frac{1}{2}$ in.; next row $\frac{1}{3}$ in.; outer row next curb $\frac{1}{2}$ in.; second row $\frac{1}{4}$ in.; and the whole of the remaining rows $\frac{1}{8}$ in. thick.

Side sheets, outer lift, bottom row $\frac{1}{4}$ in.; next 3-16ths in.; top row 3-16ths in.; intermediate rows all $\frac{1}{8}$ in. thick; inner lift, bottom and top rows 3-16ths in. thick; remainder $\frac{1}{8}$ in. thick.

Top curb is a box girder 3 ft. × 2 ft. of $\frac{3}{4}$ in. plates and $4\frac{1}{2}$ × $4\frac{1}{2}$ × $\frac{1}{2}$ in. angle-irons in the inside corners, riveted together.

Bottom curb, of 2 angle-irons, $4\frac{1}{2}$ × $4\frac{1}{2}$ × $\frac{1}{2}$ in. riveted to a $\frac{3}{4}$ in. plate 8 in. wide; the whole riveted to the lower sheet of holder.

Cup and grip formed of channel-iron 8 × 3 × 3 × $\frac{5}{8}$ in. thick; rising and dip plates $\frac{3}{8}$ in. thick and 15 in. deep; a $1\frac{1}{2}$ inch half-round iron bead is riveted to edge of rising plate.

Columns, 28, 50 ft. long, 3 ft. diameter at bottom, and 2 ft. 4 in. diameter at top; metal 1¼ in. thick at bottom and 1 in. at top.

Capacity, 1½ million cubic feet.

Inlet and outlet pipes, 30 in. diam.

Three-lift Telescopic Gasholder.

Diameter, outer lift, 214 ft. Depth, 53 ft.

Diameter, middle lift, 211 ft. Depth, 53 ft. 3 in.

Diameter, inner lift, 208 ft. Depth, 53 ft. 6 in.

Rise of crown, 14 ft.

Roof, untrussed.

Roof sheets, outer row forming part of curb, ¾ in. thick of steel plates 3 ft. wide; next row No. 7 B. wire gauge; then another row of No. 9 B. wire gauge; the remainder being all of No. 10 B. wire gauge; these latter riveted with 5-16ths in. rivets 1 in. pitch; the No. 7 B. wire gauge sheets riveted to the ¾ in. steel curb plate by ¾ in. rivets, 2½ in. pitch.

Side sheets of No. 11 B. wire gauge, secured to each other with 5-16ths in. rivets, 1 in. pitch, lap of sheets 1¼ in.; the bottom and top rows of sheets in outer lift are ¼ and 3-16ths in. thick respectively; in the middle lift 3-16ths in., and in the top lift 3-16ths and ¼ in. respectively, being riveted to the other sheeting with ⅜ in. rivets, 1¼ in. pitch, 1⅜ in. lap. Piggot's cup and dip, the former of 7-16ths in. plate, and the latter of ⅜ in. plate, secured to adjoining sheets with ⅝ in. rivets, 1¾ in. pitch, 2 in. lap; cup and dip 12 in. wide and 21 in. deep; edge of cup and dip stiffened by a 2½ × ⅝ in. flat-iron.

Top curb, formed by two ¾ in. steel plates, one forming the outer row of sheets on the crown being 36 in. wide, the other forming top row of sheets on the side 12 in. wide, these are joined together at the angle with a 5 × 5 × ¾ in. angle-steel curb, and further stiffened at the inner edge of the crown plate with a 6 × 3 × ½ in. angle-steel, all riveted together with ⅞ in. and 1 in. steel rivets, 4 in. pitch.

Bottom curb, formed by a plate ⅝ in. thick, and 15 in. wide, secured at right angles to the lower rows of sheets to a 6 × 3 × ½ in. angle-iron with ¾ in. rivets, 5½ in. pitch; another angle-iron of the same dimensions being placed 1 ft. 5 in. higher, forming a space in which are fixed the bottom roller carriages.

Vertical stays, 48, on lower and middle lifts are made of No. 10 B. wire gauge sheets bent in the form thus _∩_ 8 × 4½ in., riveted to the outside of the sheets, and on the inside opposite these are 8 × 3¼ × ½ in. channel-irons, placed between two 4 × 8 × ¼ in. angle-irons, which are riveted through the sheets to the outside stays. The top or inner lift is stiffened by No. 8 B. wire gauge sheets of the same form as above, but are 12 × 9 in., placed inside only.

Standards, 24, in the form of the letter H, 20 × 16. in. and 158 ft. 6 in. high above coping of tank, of wrought-iron formed of four 3 × 8 × ⅜ in. angle-irons ⅜ in. web plate, and ½ in. inside and outside plates, having 5 tiers of struts from standard to standard, and 10 sets of diagonal braces. Two channel-irons 8 × 8 × ½ in. riveted to each other back to back and to the standards, form the guides upon which the radial and tangential rollers work; the bottoms of standards are fastened to triangular shaped cast-iron base-plates, each secured to the tank with three 2½ in. bolts.

Capacity, 5½ million cubic feet.

Inlet and outlet pipes, 36 in. diam.

THE GOVERNOR.

An unnecessarily high pressure of gas in the mains and service-pipes is synonymous with a heavy leakage account. Ordinary valves are powerless to effect the desired pressure regulation, however well they may be attended to. No gas-works, therefore, whatever its size, should be without a station governor to control the initial pressure. When properly constructed it accomplishes this important object perfectly, however much the consumption on the one side and the density of the gas on the other may vary.

The construction of the governor is of the most simple character, consisting of a small cast-iron water-tank, through the bottom of which the gas from the regular holder enters, and makes it exit by means of a stand-pipe rising above the water level. This pipe may be either annular or rectangular in form. In the former case the gas enters by way of the central opening, and makes its exit by the annular space. In the latter arrangement the pipe is divided in two by a mid-feather, one division being the inlet and the other the outlet for the gas; the inlet division of the pipe occupying the central position in the

tank. Within the tank is a floating bell or gasholder made of tinned sheet-iron, from the crown of which a conical or parabolic shaped valve is suspended by an eye-bolt. It is the raising and lowering of this valve within the inlet gas aperture, by reason of the gas exerting a pressure of greater or less force (according as the consumption varies) on the inner surface of the floating bell, that accomplishes the necessary regulation.

The holder may be balanced or buoyed up either by means of an air chamber within itself, placed round its lower curb (Fig. 103), and consequently immersed in the water of the tank, or by chains secured to its crown outside (Fig. 102), passing over one or two pulleys and terminating in a rod carrying the required balance weights, the needed pressure being obtained by placing cast-iron or lead weights on the crown of the holder; or it may be weighted with water allowed to flow from a feed pipe into a tank formed by continuing the sides of the holder a few inches above the crown. The method of weighting by water is preferable to the other, as the pressure can be applied or removed in a more gradual manner, the opening in the supply and discharge taps being regulated as desired.

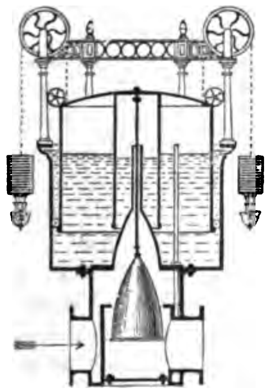


Fig. 102.

The conical valve for increasing or diminishing the area of the gas aperture has generally given place to that in the form of a parabola; the latter requiring a shorter range to produce the necessary effect, and being more delicate and certain in its action. The parabola should be made twice its diameter in length, and of weight sufficient to resist without oscillation or blinking, whatever pressure may be exerted against it by the inflowing gas. With the like object it was formerly necessary to make the floating bell with an area twenty times greater than the area of the base of the valve; but with the improvements effected in governors this is not now required, and much less space is now occupied by the apparatus.

Serious accidents have arisen from the escape of gas by the tilting of the floating bell; and, to obviate this danger, improvements have been introduced in the construction of governors.

The governor of J. and J. Braddock (Fig. 102 in section) will show what has been done in this direction. The gas enters from above the valve chamber. Over the valve, and of the same area as its base, is a compensating chamber within the bell, which is supplied with gas through a small pipe enclosing the valve rod, so placing the bell and valve in equilibrium. The bell is actuated by the outlet pressure, through a small pipe attached to the outlet branch. It will thus be seen that if by accident the bell were tilted or rent, the quantity of gas escaping would be limited to that which would be discharged through the two small pipes referred to.

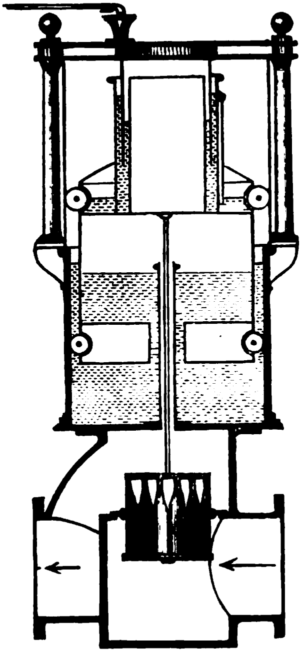


Fig. 103.

Mr. F. W. Hartley introduced a safety and regulating plate over the valve to effect the same object, and obtained compensation by means of a small tank and holder placed alongside the governor, the holder being suspended from the chain carrying the counterpoise weights.

A more recent form of governor, by J. and J. Braddock, is shown in Fig. 104, which, amongst other advantages, occupies very little space, inasmuch as the usual large bell and tank are materially reduced in size. The governor has a chamber divided into two compartments, forming inlet and outlet. The two valves are connected together and counterbalance each other, and act in opposite directions. A pressure controlling tube, open at both ends, is fitted in the top of the outlet chamber, so as to admit gas from the outlet into the bell, above the water level. As the consumption of gas decreases the pressure in the outlet chamber increases, and the bell is raised, so diminishing or shutting off, as required, the supply of gas. As the consumption of gas increases, the action is reversed. The governor is fitted with self-loading apparatus, which automatically changes the outlet pressure, according to the demand for gas.

Mr. D. Bruce Peebles employs the pressure of the inlet gas, supplied

through a small pipe having a dry regulator fixed upon it, to load the bell of the governor, which is enclosed in a gas-tight case ; and the only adjustment required is by means of small weights to the regulator.

Mr. W. Cowan has introduced various improvements in governors, by which the adjusted pressure is maintained under all variations of

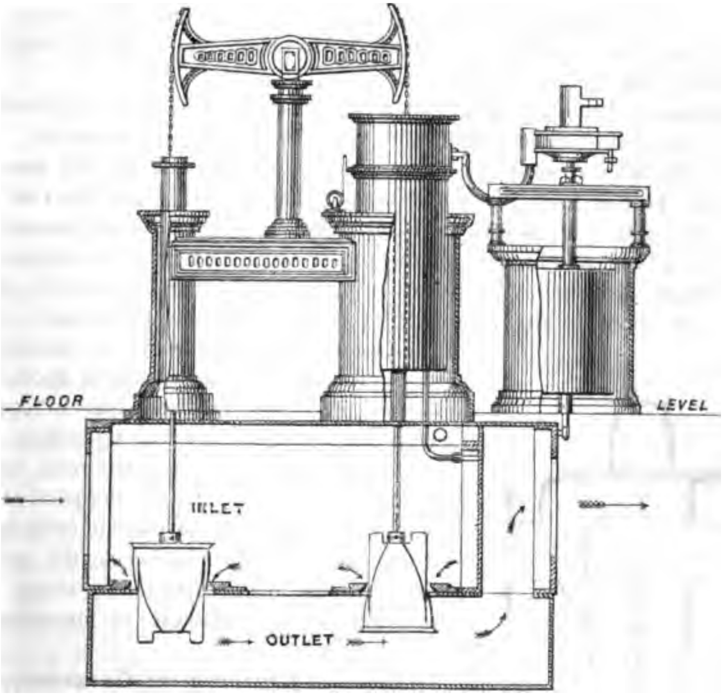


Fig. 104.

draught or changes at the inlet. (See Fig. 103.) He has also invented an "Automatic Pressure Changer," a most ingenious instrument for raising and reducing the pressure automatically at any given time, thus dispensing with the attendant, except on extraordinary occasions.

Mr. C. Hunt has adapted the ordinary throttle-valve to the purpose of a governor. By this plan a holder scarcely larger in diameter

than the main only is required. Within the supply-main leading from the works to the streets, the disc or throttle is accurately balanced on two small steel centres; the lever or radius arm by which it is actuated, being also inside the main, is attached to the centre of the disc. A small vertical pipe, communicating the holder with the main, serves to enclose the connecting-pipe attached to the radius arm and to the crown of the holder, and also conveys the gas into the latter. By means of this arrangement, a holder only 12½ inches in diameter, will actuate an 8-inch valve; and one only 17 inches diameter, an 18-inch valve.

In winter time the water in a governor tank is liable to freeze, particularly if the house containing it is in an exposed situation. A very efficient and simple remedy for this is provided by the steam stove. This is merely a cast-iron cylinder or pipe in the form of a pedestal, 2 ft. 6 in. to 3 ft. in height, and 10 or 12 in. in diameter, having a base, and an ornamental top or covering brightened by being ground and polished. The stove is placed on end on the floor of the governor room, in any convenient part, and a steam-pipe about ¾ in. in diameter, with stop-cock, is inserted through the bottom, in which is another stop-cock for letting off the water of condensation. In time of frost, by means of this stove, the atmosphere of the room can be maintained at an equable temperature, at a minimum expense. A piece of ordinary cast-iron pipe can be adapted to the purpose; on the other hand the stove is susceptible of any amount of ornamentation.

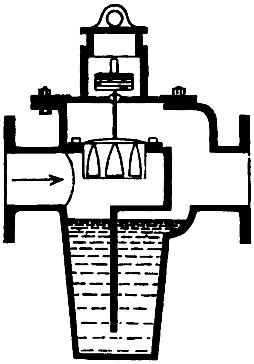


FIG. 105.

District or Differential Governor.—Gas pressure varies according to the elevation, increasing and decreasing at the rate of about one-tenth of an inch for each 10 feet of rise and fall respectively. It is thus obvious that if the pressure in the lower mains is sufficient, that in the higher mains (assuming them to be connected throughout) must be in excess.

For the supply of gas to varying levels, therefore, separate leading mains, with a station governor upon each, are highly advantageous, and should be employed wherever practicable.

District or differential governors, for the automatic regulation of the pressure in the mains at high altitudes considerably removed from the gas-works, are also of the utmost utility. These are produced both in the wet and dry form by most makers of gas apparatus. Fig. 105 shows the district governor made by D. Bruce Peebles and Co.

By doubling the amount of pressure, the consumption of gas is increased by about one-half. Leakage from a pipe is, of course, increased in the same ratio—*i.e.*, in the proportion of the square root of the pressure.

MAIN PIPES.

The leakage which arises in the distribution of gas is largely due to defective and badly jointed main pipes. Hence it is of the first importance to ensure that the pipes employed for that purpose are made of a good quality of metal, close in texture, free from defects of every kind, and as equal as possible in their sectional thickness.

To secure these three latter conditions, all cast-iron pipes 5 inches internal diameter and upwards should be cast vertically in dry sand moulds. Smaller sizes are usually cast in green sand and in inclined moulds. The pipes should be tested by hydrostatic pressure equal to at least 75 lbs. on the square inch (150 feet head of water), either at the place of manufacture or on the gas-works; and whilst under pressure they should be smartly rapped with a 3 lb. hammer from end to end. This will often reveal faults, such as sandy, porous, and blown places, not otherwise discernible. Rapping the pipes whilst on the ground will also indicate their character. If the sound emitted is clear and bell-like, the pipe may be considered free from defects. On the other hand, if dull and leaden, it is cracked or otherwise imperfect. All pipes that do not stand the tests should be rejected.

The metal of pipes, whilst compact and close, should not be excessively brittle and splintery, but such as may be readily chipped and drilled.

Cast-iron pipes below 3 in. diameter are 6 ft. long; 3 in. to 11 in. diameter, 9 ft. long; when 12 in. diameter and upwards they may be either 9 ft. or 12 ft. long. The socket is not included in these lengths.

Formula for calculating the weight of cast-iron pipes :—

$$W = 2{\cdot}45\,(D^2 - d^2).$$

Where D = outside diameter of pipe in inches.
d = inside diameter of pipe in inches.
W = weight of a lineal foot of pipe in lbs.

It is usual to pay for any overweight in the pipes beyond the weight specified not exceeding 4 per cent.

TABLE.

Cast-Iron Gas Pipes, with Open Joints.

The weight of the socket, and bead on spigot, is equal to 9-10ths of a lineal foot of the pipe, and this is included in the weights given.

Internal Diameter of Pipe.	Thickness of Metal in Body of Pipe.	Length of Socket, inside measure.	Length of Pipe, not including Socket.	Weight per Pipe, inclusive of Socket and Bead.		
Inches.	Inches.	Inches.	Feet.	Cwts.	qrs.	lbs.
1	5-16ths	2½	6	0	1	0
1½	5-16ths	2½	6	0	1	10
2	5-16ths	3	6	0	1	22
2½	3-8ths	3	6	0	2	17
3	3-8ths	3	9	1	0	11
4	3-8ths	4	9	1	1	19
5	7-16ths	4	9	2	0	7
6	7-16ths	4	9	2	1	21
7	5-10ths	4	9	3	0	27
8	5-10ths	4	9	3	2	19
9	5-10ths	4½	9	4	0	11
10	9-16ths	4½	9	5	0	16
11	9-16ths	4½	9	5	2	14
12	5-8ths	4½	12	8	3	16
13	5-8ths	4½	12	9	2	12
14	5-8ths	4½	12	10	1	8
15	5-8ths	4½	12	11	0	4
16	11-16ths	4½	12	12	3	24
17	11-16ths	4½	12	13	2	24
18	11-16ths	4½	12	14	2	0
19	3-4ths	4½	12	16	2	24
20	3-4ths	4½	12	17	2	8
21	3-4ths	5	12	18	1	20
22	13-16ths	5	12	20	3	20
23	13-16ths	5	12	21	3	8
24	7-8ths	5	12	24	2	8
30	1	5	12	35	0	0
36	1⅛th	6	12	47	0	16
42	1 3-16ths	6	12	57	3	16
48	1¼th	6	12	69	2	0

For the smaller sizes of pipes up to 8 in. diameter, the open jointing space is ⅜ in., and for larger diameters ½ in. wide all round. The following are the usual depths of the socket, inside measure, for the various sizes of open-jointed gas-pipes, plugged with yarn and lead :—

Diameter.	Depth of Socket.
Up to 3 inches	3 inches.
4 to 8 "	4 "
9 to 20 "	4½ "
21 to 30 "	5 "
32 " and upwards	6 "

TABLE.

Cast-Iron Gas Pipes, with Turned and Bored Joints, having a Recess in Front for Lead.

The weight of the socket and thickened spigot is equal to $1\frac{1}{10}$ lineal foot of the pipe, and this is included in the weights given.

Internal Diameter of Pipe.	Thickness of Metal in Body of Pipe.	Length of Socket, inside measure.	Length of Pipe, not including Socket.	Weight per Pipe, inclusive of Socket and thickened Spigot.		
Inches.	Inches.	Inches.	Feet.	Cwt.	qrs.	lbs.
1	5-16ths	2½	6	0	1	1
1½	5-16ths	2½	6	0	1	12
2	5-16ths	3	6	0	1	24
2½	3-8ths	3	6	0	2	19
3	3-8ths	3¾	9	1	0	14
4	3-8ths	4	9	1	1	22
5	7-16ths	4	9	2	0	13
6	7-16ths	4½	9	2	1	27
7	5-10ths	4½	9	3	1	8
8	5-10ths	4½	9	3	3	0
9	5-10ths	4½	9	4	0	23
10	9-16ths	4½	9	5	1	0
11	9-16ths	4½	9	5	3	1
12	5-8ths	4½	12	9	0	4
13	5-8ths	4½	12	9	3	0
14	5-8ths	4½	12	10	1	24
15	5-8ths	5	12	11	0	24
16	11-16ths	5	12	13	0	16
17	11-16ths	5¼	12	13	3	20
18	11-16ths	5¼	12	14	2	24
19	3-4ths	5¼	12	16	3	24
20	3-4ths	5¼	12	17	3	12
21	3-4ths	5¼	12	18	2	24
22	13-16ths	5¼	12	21	1	0
23	13-16ths	5¼	12	22	0	20
24	7-8ths	5¼	12	24	3	24
30	1	5¼	12	35	2	4
36	1⅛th	6	12	47	3	16
42	$1\frac{3}{16}$ths	6	12	58	3	4
48	1¼th	6	12	70	2	8

When the turned and bored joint, on being tested, is found gas-tight, it is not necessary to fill the recess with lead. The usual filling material adopted under such circumstances is Portland or Roman cement. These cements, if kneaded with warm water, set quickly; with cold water not so soon.

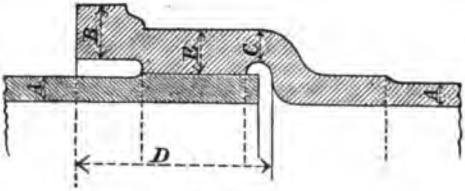


FIG. 106.

TABLE.

Dimensions of the Sockets of Turned and Bored Cast-Iron Gas Pipes, with a recess in front. (Fig. 106.)

Diameter of Pipe.	A	B	C	D	E
Inches.	Inches.	In.	In.	In.	In.
2	5-16ths	$\frac{13}{16}$	$\frac{1}{2}$	3	$\frac{3}{4}$
$2\frac{1}{2}$	3-8ths	$\frac{7}{8}$	$\frac{9}{16}$	$3\frac{1}{4}$	$\frac{13}{16}$
3	3-8ths	$\frac{15}{16}$	$\frac{5}{8}$	$3\frac{3}{4}$	$\frac{7}{8}$
$3\frac{1}{2}$	3-8ths	1	$\frac{5}{8}$	$3\frac{3}{4}$	$\frac{7}{8}$
4	3-8ths	$1\frac{1}{16}$	$\frac{11}{16}$	4	$\frac{15}{16}$
5	7-16ths	$1\frac{1}{8}$	$\frac{11}{16}$	4	$\frac{15}{16}$
6	7-16ths	$1\frac{1}{4}$	$\frac{3}{4}$	$4\frac{1}{2}$	1
7	5-10ths	$1\frac{5}{16}$	$\frac{3}{4}$	$4\frac{1}{2}$	1
8	5-10ths	$1\frac{3}{8}$	$\frac{13}{16}$	$4\frac{1}{2}$	$1\frac{1}{16}$
9	5-10ths	$1\frac{3}{8}$	$\frac{7}{8}$	$4\frac{1}{2}$	$1\frac{3}{16}$
10	9-16ths	$1\frac{7}{16}$	$\frac{7}{8}$	$4\frac{1}{2}$	$1\frac{3}{16}$
11	9-16ths	$1\frac{1}{2}$	$\frac{15}{16}$	$4\frac{1}{2}$	$1\frac{1}{4}$
12	5-8ths	$1\frac{1}{2}$	$\frac{15}{16}$	$4\frac{1}{2}$	$1\frac{1}{4}$
13	5-8ths	$1\frac{9}{16}$	$\frac{15}{16}$	$4\frac{1}{2}$	$1\frac{1}{4}$
14	5-8ths	$1\frac{9}{16}$	$\frac{15}{16}$	$4\frac{1}{2}$	$1\frac{1}{4}$
15	5-8ths	$1\frac{5}{8}$	1	5	$1\frac{5}{16}$
16	11-16ths	$1\frac{11}{16}$	1	5	$1\frac{5}{16}$
17	11-16ths	$1\frac{3}{4}$	$1\frac{1}{16}$	$5\frac{1}{4}$	$1\frac{3}{8}$
18	11-16ths	$1\frac{13}{16}$	$1\frac{1}{16}$	$5\frac{1}{4}$	$1\frac{3}{8}$
20	3-4ths	$1\frac{15}{16}$	$1\frac{1}{8}$	$5\frac{1}{4}$	$1\frac{7}{16}$

TABLE.

Dimensions of the Sockets of Turned and Bored Cast-Iron Gas Pipes, without a Recess in Front. (Fig. 107.)

Diam. of Pipe.	A	B	C	D
Inches.	Inches.	Inches.	Inches.	Inches.
2	5-16ths	$\frac{7}{8}$	$\frac{1}{2}$	3
$2\frac{1}{2}$	3-8ths	$\frac{15}{16}$	$\frac{9}{16}$	$3\frac{1}{4}$
3	3-8ths	1	$\frac{5}{8}$	$3\frac{3}{4}$
$3\frac{1}{2}$	3-8ths	$1\frac{1}{8}$	$\frac{5}{8}$	$3\frac{3}{4}$
4	3-8ths	$1\frac{1}{4}$	$\frac{11}{16}$	4
5	7-16ths	$1\frac{3}{8}$	$\frac{11}{16}$	4
6	7-16ths	$1\frac{1}{2}$	$\frac{3}{4}$	$4\frac{1}{2}$
7	5-10ths	$1\frac{9}{16}$	$\frac{3}{4}$	$4\frac{1}{2}$
8	5-10ths	$1\frac{5}{8}$	$\frac{13}{16}$	$4\frac{1}{2}$
9	5-10ths	$1\frac{11}{16}$	$\frac{7}{8}$	$4\frac{1}{2}$
10	9-16ths	$1\frac{3}{4}$	$\frac{7}{8}$	$4\frac{1}{2}$
11	9-16ths	$1\frac{15}{16}$	$\frac{15}{16}$	$4\frac{1}{2}$
12	5-8ths	$1\frac{15}{16}$	$\frac{15}{16}$	$4\frac{1}{2}$
13	5-8ths	$1\frac{7}{8}$	$\frac{15}{16}$	$4\frac{1}{2}$
14	5-8ths	$1\frac{7}{8}$	$\frac{15}{16}$	$4\frac{1}{2}$
15	5-8ths	2	1	5
16	11-16ths	2	1	5
17	11-16ths	$2\frac{1}{8}$	$1\frac{1}{16}$	$5\frac{1}{4}$
18	11-16ths	$2\frac{1}{8}$	$1\frac{1}{16}$	$5\frac{1}{4}$
20	3-4ths	$2\frac{1}{4}$	$1\frac{1}{8}$	$5\frac{1}{4}$

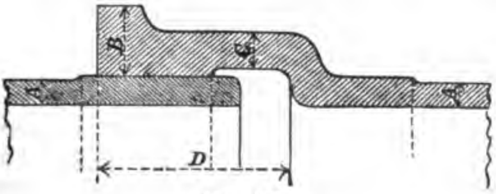


FIG. 107.

TABLE.

Cast-Iron Gas Pipes, with Flange Joints.

The weight of the flanges is equal to 1 lineal foot of the pipe, and this is included in the weights given.

Internal Diameter of Pipe.	Thickness of Metal in Body of Pipe.	Flanges. Diameter across Flanges.	Flanges. Thickness of Metal.	Flanges. Number of Bolt Holes.	Flanges. Diameter, centre to centre, of Bolt Holes.	Flanges. Diameter of Bolts.	Length of Pipe outside the Flanges.	Weight per Pipe inclusive of the Flanges. Cwts.	qrs.	lbs.
Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Feet.	Cwts.	qrs.	lbs.
1	5-16ths	4	7/16	3	2 7/8	5/16	6	0	1	0
1½	5-16ths	4½	7/16	3	3 3/8	3/8	6	0	1	11
2	5-16ths	6¼	½	4	4¾	7/16	6	0	1	22
2½	3-8ths	7¼	9/16	4	5¼	½	6	0	2	18
3	3-8ths	7½	9/16	4	5½	½	9	1	0	11
4	3-8ths	9	9/16	4	7	½	9	1	1	22
5	7-16ths	10¼	5/8	4	8¼	5/8	9	2	0	10
6	7-16ths	11½	5/8	4	9½	5/8	9	2	1	24
7	5-10ths	13	¾	4	11	5/8	9	3	1	5
8	5-10ths	14½	¾	6	12	5/8	9	3	2	25
9	5-10ths	16	¾	6	13½	5/8	9	4	0	17
10	9-16ths	17¼	7/8	6	14¾	5/8	9	5	0	22
11	9-16ths	18¼	7/8	6	15¾	¾	9	5	2	20
12	5-8ths	19½	15/16	6	16½	¾	12	8	3	24
13	5-8ths	20½	15/16	6	17½	¾	12	9	2	20
14	5-8ths	21½	1	8	18½	¾	12	10	1	16
15	5-8ths	22½	1	8	19½	7/8	12	11	0	12
16	11-16ths	24	1 1/16	8	21	7/8	12	13	0	8
17	11-16ths	25	1 1/16	8	22	7/8	12	13	3	8
18	11-16ths	26	1⅛	10	23	7/8	12	14	2	12
19	3-4ths	27	1⅛	10	24	7/8	12	16	3	12
20	3-4ths	28	1⅛	10	24½	7/8	12	17	2	24
21	3-4ths	29	1⅛	10	25½	7/8	12	18	2	8
22	13-16ths	30	1 3/16	10	26½	7/8	12	21	0	8
23	13-16ths	31	1¼	10	27½	7/8	12	22	0	0
24	7-8ths	32	1 5/16	12	28½	7/8	12	24	3	0
30	1	38	1½	14	34½	1	12	35	1	0
36	1⅛th	45	1½	18	41½	1	12	47	2	0
42	1 3/16ths	51	1⅝	20	47½	1	12	58	1	8
48	1¼th	57	1¾	24	53½	1	12	70	0	4

Cast-iron in cooling from the molten condition shrinks one-eighth of an inch per foot.

Main Pipe Joints.—A host of joints for main pipes have been invented from time to time, which, though theoretically good, have not all proved very satisfactory in practice. The classes of joint generally in

use are the turned and bored, and the open joint. The ball and socket joint is employed under exceptional circumstances, as when the main has to be laid in the bed of a river or harbour, or across a narrow arm of the sea.

A difference of opinion exists among engineers as to which form of joint is best—the turned and bored, or the open joint filled with lead, rust cement, or other substance, metallic or otherwise. We, who have had large experience in both, and under most circumstances, prefer the turned and bored, both for ease in adjustment, economy, and efficiency.

In districts where the ground is extensively undermined and liable to subsidence, the vulcanized india-rubber joint (which is virtually an open joint) is the most suitable. (Fig. 111.)

Special pipes, such as bends, tees, and junctions are, for convenience sake, made with open joints. (Fig. 114.)

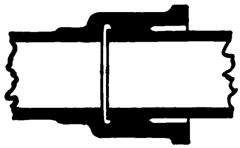


FIG. 108.

The turned and bored joint is shown in Fig. 108.

There is no difficulty in swinging round ordinary curves with a line of mains jointed in this manner; but when the radius of the curve is short, an occasional yarn and lead joint is required.

In specifying for pipes with these joints, care should be taken that the bored and turned surfaces are not made with too much taper; indeed, the nearer the surfaces approach to parallel lines without being absolutely parallel, the better they will fit.

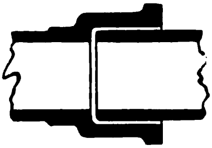


FIG. 109.

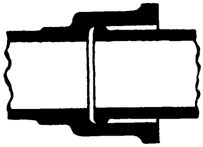


FIG. 110.

The socket may either be bored flush up to the face, as in Fig. 107, or it may have a recess in front, as in Figs. 106 and 108. The latter is to be preferred, as it can be supplemented with lead or other filling should the turned joint prove defective.

Two examples of the open joint are given in Figs. 109 and 110.

The india-rubber joint (Fig. 111) is formed by passing a vulcanized ring of that material round the spigot end of the pipe, which is specially cast with a groove and bead to suit this description of joint.

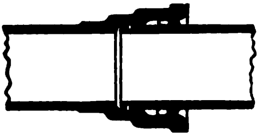


Fig. 111.

When the pipe end is pushed forward into the socket, the ring is compressed or flattened, and butts against the raised bead. No other packing is necessary, so that it is an expeditious method of jointing, whilst the vulcanized india-rubber, unaffected by the presence of gas or moisture, is practically indestructible. The other advantages of this joint have already been referred to.

The ball and socket joint is shown in Fig. 112. This particular form is the invention of Mr. J. Z. Kay, and has been successfully employed for main pipes crossing through rivers and harbours where

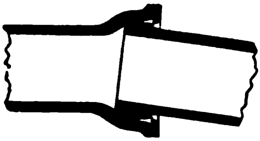


Fig. 112.

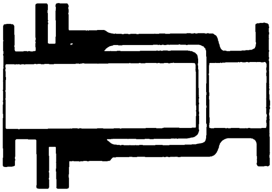


Fig. 113.

the ordinary rigid joint is inapplicable. The lead is first run in and caulked; and the connected pipes, being like a chain, can be paid out of a lighter, or other vessel, when they will find their own bed in the river bottom.

The expansion joint (Fig. 113) is useful in all cases where a line of main is exposed to varying temperatures, as in pipes placed against a wall or alongside a bridge, or in an open trench or channel.

Mill-board or engine-board coated with red or white lead, makes a good and durable joint for flanges.

A combination of asbestos and india-rubber woven sheeting, makes a superior flange joint, especially for steam purposes, as these substances resist the action of both heat and moisture. To prevent adherence to the iron (in the case of blank-flange and manhole joints that require to be frequently broken), the flange should be rubbed over with powdered black lead before placing the cover.

Metallic rings are commonly used for flange joints. These are best made with $\frac{1}{4}$ inch or $\frac{3}{8}$ inch lead pipe, with the ends soldered evenly together; the ring is then covered with flax, and well smeared with red lead or paint. The pipe must not be beaten flat, but left round, so that when the joint is screwed up it may bed into any irregularities in the surfaces. The remaining space between the flanges is filled with rust or other cement.

Flange pipes can be jointed without the interposition of any packing material, by having the flanges faced in a lathe. In such case the surfaces are merely coated with white lead paint, and the joint tightened up.

Bolts used for jointing flanges, &c., should have a gummet of flax or tow, smeared with red or white lead, placed round their neck to bed under the head when screwed up.

Red and white lead should always be mixed with boiled linseed oil. Other oil can be made to answer, but not nearly so well.

The bends, tees, junction pipes, and other irregulars required in the distributing department of a gas-works, are shown on page 206.

Gas pipes should be free from excrescences, and moderately smooth on their inner surface.

They are better not coated internally with any kind of substance soluble in naphtha or other hydrocarbon liquid. Such coating is soon dissolved by the gas, and drains partially away into the drip wells; the residue collecting into viscid masses at different points, principally near to the joints. The coating can only be intended to reduce friction by rendering the surface joint smooth for the passage of the gas, because as a preservative to the iron, internally, it is not required. Its effect is to impede the flow. The slight deposit which takes place from the gas alone soon gives the metal a smooth coating. These objections do not, of course, apply to the internal coating of water-pipes.

It is only for appearance sake, as a rule, that a covering of this description can be recommended for the outside of cast-iron pipes. It often serves only to hide defects in the casting.

The reddish-brown oxide covering which cast-iron pipes acquire in a short time, when laid in ordinary soil, is one of the best perservatives of the metal. This covering is impervious to moisture, its effect being to arrest further corrosive action.

There are, however, circumstances where it is desirable and necessary to coat pipes externally, as, for example, when they are of

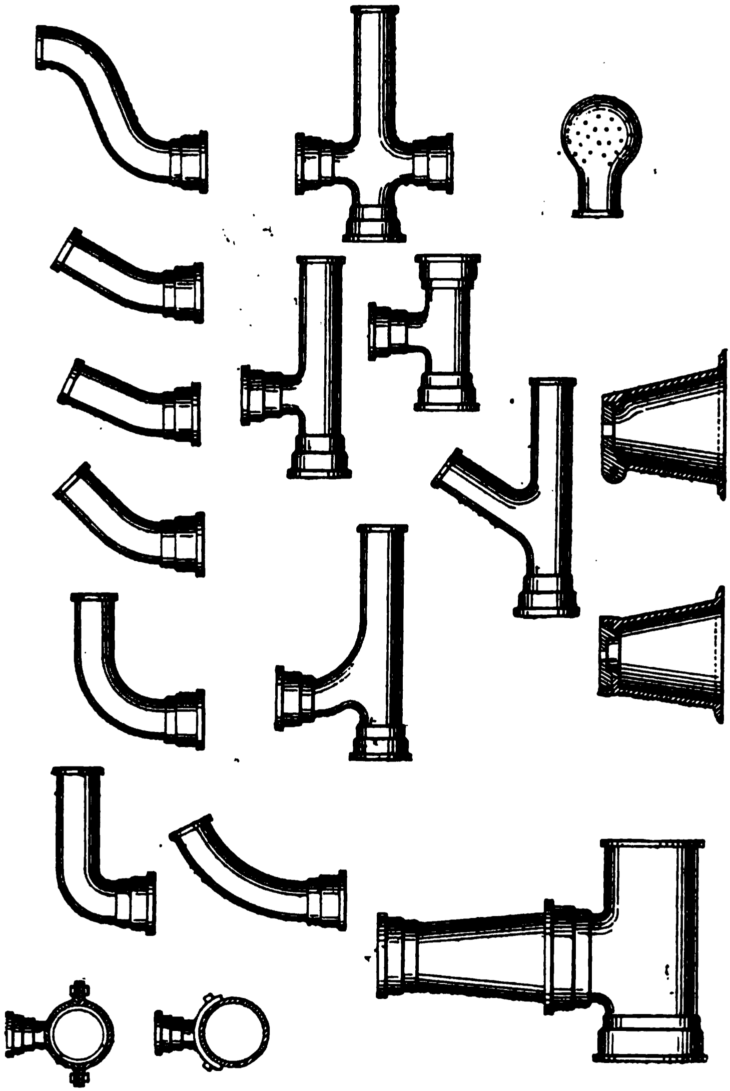


Fig. 114.

wrought-iron, and when, though of cast-iron, they are to be laid in soils intermixed with engine ashes, furnace slag, vitrified cinders, clinker, dross, scoriæ, or chemical refuse of any kind.

Wrought-iron and Steel Main Pipes.—Of recent years a considerable trade has sprung up in the manufacture of wrought-iron and steel main pipes of large diameter for foreign countries. Although the first cost of these is greater than that of the same sizes in cast-iron, yet owing to their being lighter and less liable to fracture, the reduced expense of freight and haulage to their destination makes their ultimate cost, length for length, materially less. The wrought-iron pipes are lap-welded, and those of the steel are riveted in the seam. They are generally in 15 feet lengths. The next table gives the usual thickness and weight of wrought-iron pipes.

TABLE.

Thickness and Weight of Wrought-iron Main Pipes.

Diameter Inside. Inches.	Thickness. Inches.	Weight per Foot. Pounds.
3	5-32 full.	6
3½	5-32 full	7
4	3-16	9
5	3-16	10½
6	3-16	13
7	1-4 bare.	18
8	1-4 bare.	20
9	1-4 bare.	24½
10	1-4	28
12	1-4	33
14	5-16	43
16	5-16	50

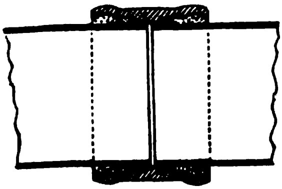


FIG. 115.

The smaller sizes, 3 in., 3½ in., and 4 in. diameter have screwed ends and sockets. The larger diameters may be either screwed or plain. In the latter case the "Kimberley" collar (Fig. 115) is employed for connecting them; this is also made of wrought-iron.

TABLE.

Weight of Lead required for Jointing Wrought-iron Main Pipes with the "Kimberley" Collar.

Internal Diameter of Pipe. Inches.	Depth of Lead on each side of Collar. Inches.	Weight of Lead. Pounds.	Internal Diameter of Pipe. Inches.	Depth of Lead on each side of Collar. Inches.	Weight of Lead. Pounds.
5	1¾	8¾	10	1¾	16½
6	1¾	10	11	1¾	18
7	1¾	11¾	12	1¾	20
8	1¾	13½	14	2	26
9	1¾	15	16	2	30

The Laying of Main Pipes.—Special care is needed in the laying of main pipes. As a general rule the covering of soil over them should be at least 21 inches deep, to protect them from breakage by steam-rollers, the influences of heavy traffic and low and varying temperatures.

The excavation to receive the pipes should not be unnecessarily wide, as the less filling up that is required the better, not to mention the saving in cost.

The bottom of the trench on which the pipes rest should be even and firm, and if not so, then thoroughly consolidated by punning. The soil should be scooped out at the various points in the trench bottom, where the sockets come, so that the body of the pipe may lie solid throughout its length. In cases where this cannot well be done resort may be had to underpinning.

Each pipe should be laid with the proper inclination or fall, and securely jointed; all joints being proved either with gas or air under high pressure while the trench is open.

In roads or footpaths made with ashes or chemical refuse, the pipes should be carefully embedded in good common soil obtained for that purpose, or puddled round with clay—especially protecting the upper side with a thick covering.

It is worse than useless to place clay *only underneath* the pipe. When so placed, it serves to receive and retain the water, which, percolating through the material forming the ground, is charged with acid bisulphides and other deleterious compounds. The metal of the pipe thus lying, as it were, in a bath of acidulous liquid, is destroyed

sooner than it would be if no clay were present. The protection afforded by the clay should therefore be complete, all round the pipe, and particularly over its upper surface.

In refilling the trench, the soil should be shovelled in in layers, and rammed firmly and equally all round and above the pipes.

Gas pipes laid through arable land do it no harm, but rather good, inasmuch as they help to drain the land. The joints should be perfect, however, as the escape of gas is fatal to vegetable life.

When laying pipes with bored and turned joints, the spigot and socket ends, after being cleaned with cotton waste, are coated with thick paint composed of one part each white and red lead mixed with boiled linseed oil; the end is then inserted and driven home with a mallet, or, should the pipe be large, with a swing block. Or another pipe swung from the shear-legs may be used. In this case a wood shield should be laid against the socket to take the force of the blow.

In driving the pipes they will sometimes be found to spring back at every stroke. This may be due either to the surfaces being made too conical, in which case it is difficult to ensure a good joint; or there is a slight ridge or roughness on the inner edge of the bored part of the socket. Chip this off with a sharp chisel.

Red lead sets sooner and harder than white; and the following reason is given for preferring the white to the red for joints:—When an expansion or contraction takes place in the pipes, the red lead is liable to crack, and so cause a leakage; whereas the white lead is more tractable, and better adapts itself to the varying circumstances. An equal mixture of the two is preferable.

In placing pipes with open joints, twined gasket is caulked in all round so as to fill nearly half the length of the open space. A roll of tough plastic clay is then passed round and pressed against the socket face, and through a lip on the upper side molten lead is poured till the remaining space is filled. On the lead being set up with a blunt caulking tool and hammer the joint is complete.

The ladle should contain sufficient molten lead to fill the joint at one pouring, otherwise the adhesion of the metal throughout will not be perfect.

Molten lead, when heated to redness, will fly when poured upon a wet or damp surface.

Mains in level ground should be laid with a slight inclination, say 1 foot in 400 yards, and at each lowest point a syphon or drip-well

(Fig. 116), of cast-iron, should be placed underneath, and connected by a tube to the pipe to receive the liquid arising from condensation. Another form of syphon, with sockets to receive the main pipes, is shown in Fig. 117. In all cases where a main dips, a syphon is required at the place where the dip is reversed.

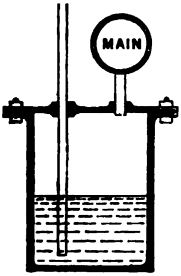


FIG. 116.

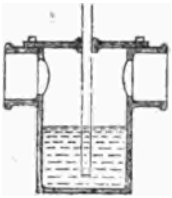


FIG. 117.

The liquor from these receptacles is pumped out periodically into a cask on wheels, and deposited in the tar-well on the gas-works.

In laying down mains in lieu of others of a smaller size, the difference in value between the two sizes of pipes only should be charged to capital account.

TABLE

Giving the Weight of Lead in Pounds required for Jointing Cast-Iron Mains.

Diameter of Pipe in Inches.	Depth of Lead in Inches.	Weight of Lead in Pounds.	Diameter of Pipe in Inches.	Depth of Lead in Inches.	Weight of Lead in Pounds.
1½	1⅜	1¼	11	2¼	16½
2	1½	1¾	12	2⅜	18½
2½	1⅝	2¼	13	2⅜	21
3	1⅝	2¾	14	2⅜	23½
4	1¾	4	15	2½	26
5	1⅞	5¼	16	2½	28½
6	2	7	17	2½	31
7	2	8¾	18	2⅝	32½
8	2⅛	10¼	19	2⅝	34
9	2⅛	12¼	20	2⅝	35½
10	2¼	14½	24	3	48

For pipes 1½ to 8 inches in diameter the lead is assumed to be about ⅜-inch thick; and in pipes 9 inches in diameter and upwards, ½-inch thick.

In place of lead, rust cement and a mixture of beeswax and tallow are used for jointing mains. "Spence's metal" also is an efficient substitute, and its cost is considerably less.

Iron or Rust Cements for Flange and Open Socket Joints.

(1) 1 lb. of clean iron borings, pounded fine in a mortar.
2 oz. sal ammoniac (muriate of ammonia) in powder.
1 oz. flowers of sulphur.

Mix the whole together by pounding and keep dry. For use, mix one part with twenty of iron borings pounded, adding water to the consistency of mortar.

(2) 98 parts fine iron borings.
1 part flowers of sulphur.
1 part sal ammoniac.

Mix, and when required for use, dissolve in boiling water. This cement sets quickly.

If required to set slowly, which makes the better joint—

(3) 197 parts iron borings.
1 part flowers of sulphur.
2 parts sal ammoniac.

When required for use, mix with boiling water.

The iron borings used for making joints should be perfectly free from grease and oil.

The cubical content of the joint in inches, divided by 5, gives the weight in pounds of iron cement required.

Appliances used in Mainlaying.—In beginning to lay an extensive length of main pipes, considerable delay, and consequent loss, is often experienced at first, owing to a want of foresight in providing beforehand the necessary men, tools, and other appliances required. The following is an enumeration of what is necessary to be provided, varying according to the peculiarities of the district and the extent of the work to be done:—

One or two skilled main-layers.

A number of labourers according to the extent of the work.

A paviour and his labourer. A night watchman.

A pick and spade (and a tool, if clay) for each labourer.

A supply of picks, pick-handles, and wedges should be kept in stock to replace broken ones.

A screen for separating stones and soil.

Shear-legs or tripod; or, what is better, if the mains are of large diameter, a moveable pipe-layer, supported on wheels, running on rails laid alongside of the trench.

Blocks, tackle, and ropes or chain.

A chain or clip to encircle the pipes.

Eight hand-spikes of wood, for moving the pipes about.

Two pieces of 2 or 3 inch wrought-iron tube (according to the size of main), on which to roll the pipe previous to lowering it to its place in the trench.

Two or four long iron bars, and two short ones.

Two planks for long and strong leverage.

Red and white lead, mixed with boiled oil, if turned and bored joints.

Some cotton waste and old cards to clean the joints, if turned and bored. A supply of spun yarn and lead, if open joints.

A wooden mallet for driving small bored and turned pipes.

Two or four oak blocks, strengthened with bolts or hoops, to lay against the pipe-sockets when driving

A 3 or 4 inch cast-iron pipe, to swing with a rope or chain from centre of shear-legs when driving, or a wooden spring block if preferred.

Wood plugs for the various sizes of pipes and branches.

India-rubber cloth bags for plugging the mains. (See Fig. 118.)

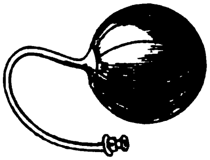


Fig. 118.

A lead pot and two ladles.

Chisels and caulking tools.

Tarred rope for trying the joints and pipes.

A coke fire-grate for melting the lead and for use by the night watchman.

Three setts, with handles, for cutting any pipes required.

Two large hammers, 7 lbs. weight, and several smaller ones, 1½, 2, and 3 lbs. each.

Screwing tackle.

Some fine flax for indifferent joints.

A few casks of cement.

A bogie or hand-drag, and two or three hand-barrows.

Portable bench, with vice attached.

Covered hand-cart, under lock and key.

A supply of good soil for bedding the pipes, and to prevent the contact of ashes, if such should be present in the cutting.

A spirit-level and a straight-edge 10 or 14 feet long.

A supply of planking to cover up any part of the trench temporarily.

A box for the night watchman.

Two red signal lamps to warn passengers of the open trench during the dark hours.

Two stand-pipes for the signal lights.

Apparatus for proving the mains for leakage before filling up the trench.

Look up beforehand what bends, tees, thimbles, flanges, drip-wells, and other special castings will be required in the course of the work, and have them in readiness when needed.

In enlarging or replacing pipes, many services require to be coupled up and renewed, and in that case service-layers and tools should be in readiness.

EXPLOSIONS IN MAIN PIPES.

In the laying of large main pipes, due care and diligence should be exercised by the skilled and responsible officials in charge of such work. Calamitous explosions have occurred owing to neglect in these particulars.

Such an explosion took place in London in 1862, and again in 1880; and one in Manchester, in 1873, when a large cast-iron syphon-well was being attached to a main.

Coal gas when unmixed with air or oxygen, as is well known, is perfectly inexplosive, and is even incombustible. It is only when the gas comes in contact with the oxygen of the air, as at the burner for example, that it can be ignited; combustion being in fact the union in the presence of heat of the hydrogen and carbon of the gas with atmospheric oxygen.

Explosions of the kind referred to are produced by a mixture of gas and air in certain proportions. The explosive force of a compound of this character is greatest when gas is mixed with eight times its bulk of air.

Under ordinary circumstances it is impossible for air to become mixed with the gas in the street mains. This can only occur when a main is in course of being laid, or when a fresh junction is being made with an existing main.

In the case of the London explosions referred to, a new main was being laid. In order to allow of this being done, the gas was either

wholly or partially shut off at the junction with the live main. Probably the gas was only partially excluded; and the limited quantity entering would, by the operation of the law of the diffusion of gases, gradually mix with the air existing in the new length of main, till it became charged throughout its course, with a dangerously explosive compound. On the application of a light, either accidentally or from intention, the mixture was ignited, with disastrous consequences to life and property.

It is not necessary that there should be the presence of actual flame to cause ignition. Dr. Frankland and other authorities have demonstrated the fact, well known to most gas engineers, that explosive mixtures of coal gas and air may be inflamed by a spark struck from stone or metal; that ignition may be caused by a spark produced from the hammer and chisel of a workman, or even from the tramp of a horse upon the pavement.

There is no absolute necessity that the gas should be excluded from such an extent of main pipes in course of being laid as to incur the risk of accident; because the main for a short space from the point where the junction is being made can readily be closed by the ordinary india-rubber valves. When the main is of such large diameter as to preclude the possibility of a valve of this kind being used, the utmost precaution is necessary to ensure the expulsion of the air before a light is applied to test the soundness of the joints.

Under any circumstances the application of a light is objectionable and unnecessary, as the joints can be proved when the main is under pressure by brushing them over with a solution of soap in water.

TESTING OF GAS-MAINS IN THE GROUND.

The reduction of the loss of gas by leakage during recent years is remarkable. It is safe to estimate that twenty to twenty-five years ago, the unaccounted-for gas averaged sixteen per cent. of the gas produced. At the present time the average is only one-half that figure, or eight per cent. This reduction is largely due to the closer attention that is given to the pressures by day and night; to the use of governors in street lighting; and to the better supervision that is exercised in the laying of mains and service-pipes.

It may be stated as a salutary rule, that the maximum initial pressure in a district during the hours of the heaviest consumption, should

not exceed 20-tenths. When there is found to be a necessity for more, the trunk mains, or some of the most contracted mains branching therefrom, should be replaced by larger ones.

Considerable expense must be incurred in any systematic attempt to reduce leakage; but wherever in a district the unaccounted-for gas exceeds 10 per cent. of the make, the expenditure is not only justifiable on sanitary and other grounds, but is eventually found to be a good and profitable investment.

Various appliances have been devised for testing gas mains in the ground. Brothers' apparatus consists simply of two 80-light meters,

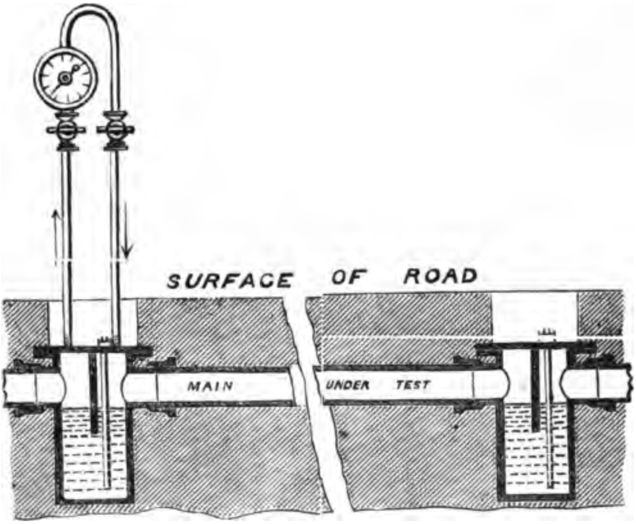


FIG. 119.

one of which registers the passage of gas in the usual way; and the other is made to act as an exhauster, either by continuing the spindle of the drum through the casing and attaching a handle to it, or by means of a small wheel geared into a larger one on the periphery of the drum—the former being actuated by a handle from the outside. The main having been severed, and the two ends carefully plugged, the exhauster inlet is connected to the live main, and the meter outlet to the dead section of main; the exhauster and meter also being joined. On the exhauster being gently turned, gas is drawn from the

live main, and forced through the meter into the length of main under test, and thus the amount of loss in a certain time and under a given pressure is indicated.

The great cost is in cutting the pipes, reinstating them, and finding the exact locality of the escape. To obviate the necessity of severing the pipes, a suggestion was made at the meeting of the Manchester District Institution of Gas Engineers in November 1879, that water-valves or traps which would also answer the purpose of drip wells, might be permanently placed at intervals in the line of mains. These traps, having a diaphragm extending to within a regulated distance of the bottom, on being charged with water, would form a hydraulic valve, shutting off the gas from any section of main as desired, and enabling a test to be made without difficulty and at reduced expense.

Acting on this suggestion, Mr. J. H. Lyon has introduced an improved syphon box or hydraulic valve, for attaching to mains, and by means of a leakage indicator affixed to stand pipes on each side of the box or valve, the quantity of gas escaping is readily ascertained. (See Fig. 119.)

TABLE

Showing the Average Cost per Yard of Laying Mains, 9 feet long each, with Turned and Bored Joints, and with Lead Joints, including the Total Expenses of Material (the Pipes excepted), Excavating, Reinstating, and Maintaining the Ground for Six Months after Completion. Average Depth from the Surface of the Ground to the Upper Side of the Pipe, 1 foot 9 inches.

Diameter in Inches.	2.		2½.		3.		4.		5.		6.	
Description of Joint.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
In ordinary ballast	0 8	1 0	0 9	1 1	0 10	1 2	1 3	1 7	1 6	2 0	1 7	2 2
In roads macadamized with Welsh or limestone	0 11	1 3	1 0	1 5	1 2	1 6	1 7	1 11	1 9	2 4	1 11	2 6
In ordinary paved streets	1 0	1 4	1 1	1 6	1 4	1 8	1 8	2 0	2 1	2 7	2 3	2 10
In bituminized streets	3 2	3 6	3 3	3 9	3 6	4 2	5 0	5 6	5 3	6 0	5 7	6 2
In footpaths made with sand or ashes	0 6	0 11	0 7	1 0	0 8	1 0	0 11	1 3	1 4	1 10	1 5	2 0
In footpaths flagged	0 8	1 0	0 9	1 1	0 10	1 2	1 3	1 7	1 6	2 0	1 7	2 2
In footpaths asphalted	1 10	2 2	2 0	2 4	2 2	2 8	2 7	3 0	2 10	3 4	2 11	3 6

Diameter in Inches.	7.		8.		9.		10.		11.		12.	
Description of Joint.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
In ordinary ballast	1 10	2 6	2 1	2 10	2 2	3 0	2 6	3 6	2 8	3 10	2 11	4 2
In roads macadamized with Welsh or limestone	2 2	2 10	2 5	3 2	2 6	3 4	2 10	3 10	3 1	4 3	3 4	4 7
In ordinary paved streets	2 5	3 1	2 8	3 5	2 9	3 7	3 1	4 1	3 4	4 6	3 7	4 10
In bituminized streets	5 10	6 9	6 1	7 2	6 2	7 6	6 6	8 0	6 8	8 4	7 11	9 8
In footpaths made with sand or ashes	1 7	2 3	1 11	2 8	2 0	2 10	2 4	3 4	2 6	3 8	2 9	4 0
In footpaths flagged	1 10	2 6	2 1	2 10	2 2	3 0	2 6	3 6	2 8	3 10	2 11	4 2
In footpaths asphalted	3 2	3 10	3 5	4 3	3 6	4 4	3 10	4 10	4 0	5 2	4 4	5 7

Diameter in Inches.	13.		14.		15.		16.		17.		18.	
Description of Joint.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
In ordinary ballast	3 3	4 9	3 5	5 2	3 9	5 7	4 4	6 5	4 8	7 0	5 0	7 5
In roads macadamized with Welsh or limestone	3 8	5 2	3 10	5 7	4 2	6 0	4 9	6 10	5 2	7 6	5 6	7 11
In ordinary paved streets	3 11	5 5	4 1	5 10	4 5	6 3	5 0	7 1	5 4	7 8	5 8	8 1
In bituminized streets	8 3	10 3	8 5	10 8	9 0	11 4	9 8	12 3	10 0	12 10	10 6	13 6
In footpaths made with sand or ashes	3 0	4 7	3 3	5 0	3 7	5 5	4 2	6 3	4 6	6 10	4 10	7 3
In footpaths flagged	3 3	4 9	3 5	5 2	3 9	5 7	4 4	6 5	4 8	7 0	5 0	7 5
In footpaths asphalted	4 9	6 3	5 0	6 9	5 3	7 1	5 10	7 11	6 2	8 6	6 6	9 0

Diameter in Inches.	19.		20.		21.		22.		23.		24.	
Description of Joint.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.	Turned and Bored.	Lead.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
In ordinary ballast	5 8	8 2	6 3	8 10	6 8	9 4	7 1	9 9	7 4	10 0	7 7	11 2
In roads macadamized with Welsh or limestone	6 2	8 8	6 9	9 4	7 2	9 10	7 7	10 3	7 10	10 6	8 1	11 8
In ordinary paved streets	6 4	8 10	7 0	9 7	7 5	10 1	7 10	10 6	8 1	10 9	8 4	12 0
In bituminized streets	11 10	15 2	12 6	16 0	13 0	16 6	13 6	17 0	13 8	17 3	14 0	18 6
In footpaths made with sand or ashes	5 6	8 0	6 0	8 7	6 6	9 2	6 10	9 6	7 2	9 10	7 4	11 0
In footpaths flagged	5 8	8 2	6 3	8 10	6 8	9 4	7 1	9 9	7 4	10 0	7 7	11 2
In footpaths asphalted	7 2	9 9	7 9	10 4	8 2	10 10	8 7	11 3	8 10	11 6	9 1	13 3

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 2, 3, and 4 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	2.			3.			4.		
Class of Joint.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	25	26	25	41	42	41	53	54	54
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	0 11	0 11	0 11	1 6	1 6	1 6	1 11	1 11	1 11
4 2 6 ,,	0 11	0 11	0 11	1 6	1 7	1 6	1 11	2 0	2 0
4 5 0 ,,	0 11	1 0	0 11	1 7	1 7	1 7	2 0	2 1	2 1
4 7 6 ,,	1 0	1 0	1 0	1 7	1 8	1 7	2 1	2 1	2 1
4 10 0 ,,	1 0	1 1	1 0	1 8	1 8	1 8	2 2	2 2	2 2
4 12 6 ,,	1 0	1 1	1 0	1 8	1 9	1 8	2 2	2 3	2 3
4 15 0 ,,	1 1	1 1	1 1	1 9	1 9	1 9	2 3	2 3	2 3
4 17 6 ,,	1 1	1 2	1 1	1 9	1 10	1 9	2 4	2 4	2 4
5 0 0 ,,	1 1	1 2	1 1	1 10	1 11	1 10	2 4	2 5	2 5
5 2 6 ,,	1 2	1 2	1 2	1 11	1 11	1 11	2 5	2 6	2 6
5 5 0 ,,	1 2	1 3	1 2	1 11	2 0	1 11	2 6	2 6	2 6
5 7 6 ,,	1 2	1 3	1 2	2 0	2 0	2 0	2 7	2 7	2 7
5 10 0 ,,	1 3	1 3	1 3	2 0	2 1	2 0	2 7	2 8	2 8
5 12 6 ,,	1 3	1 4	1 3	2 1	2 1	2 1	2 8	2 9	2 9
5 15 0 ,,	1 3	1 4	1 3	2 1	2 2	2 1	2 9	2 9	2 9
5 17 6 ,,	1 4	1 4	1 4	2 2	2 2	2 2	2 9	2 10	2 10
6 0 0 ,,	1 4	1 5	1 4	2 2	2 3	2 2	2 10	2 11	2 11
6 2 6 ,,	1 4	1 5	1 4	2 3	2 4	2 3	2 11	2 11	2 11
6 5 0 ,,	1 5	1 5	1 5	2 3	2 4	2 3	2 11	3 0	3 0
6 7 6 ,,	1 5	1 6	1 5	2 4	2 5	2 4	3 0	3 1	3 1
6 10 0 ,,	1 5	1 6	1 5	2 5	2 5	2 5	3 1	3 2	3 2
6 12 6 ,,	1 6	1 6	1 6	2 5	2 6	2 5	3 2	3 2	3 2
6 15 0 ,,	1 6	1 7	1 6	2 6	2 6	2 6	3 2	3 3	3 3
6 17 6 ,,	1 6	1 7	1 6	2 6	2 7	2 6	3 3	3 4	3 4
7 0 0 ,,	1 7	1 8	1 7	2 7	2 8	2 7	3 4	3 5	3 5
7 2 6 ,,	1 7	1 8	1 7	2 7	2 8	2 7	3 4	3 5	3 5
7 5 0 ,,	1 7	1 8	1 7	2 8	2 9	2 8	3 5	3 6	3 6
7 7 6 ,,	1 8	1 9	1 8	2 8	2 9	2 8	3 6	3 7	3 7
7 10 0 ,,	1 8	1 9	1 8	2 9	2 10	2 9	3 7	3 7	3 7
7 12 6 ,,	1 8	1 9	1 8	2 9	2 10	2 9	3 7	3 8	3 7
7 15 0 ,,	1 9	1 10	1 9	2 10	2 11	2 10	3 8	3 9	3 9
7 17 6 ,,	1 9	1 10	1 9	2 11	2 11	2 11	3 9	3 10	3 10
8 0 0 ,,	1 9	1 10	1 9	2 11	3 0	2 11	3 9	3 10	3 10
8 2 6 ,,	1 10	1 11	1 10	3 0	3 1	3 0	3 10	3 11	3 11
8 5 0 ,,	1 10	1 11	1 10	3 0	3 1	3 0	3 11	4 0	4 0
8 7 6 ,,	1 10	1 11	1 10	3 1	3 2	3 1	4 0	4 0	4 0
8 10 0 ,,	1 11	2 0	1 11	3 1	3 2	3 1	4 0	4 1	4 1
8 12 6 ,,	1 11	2 0	1 11	3 2	3 3	3 2	4 1	4 2	4 2
8 15 0 ,,	1 11	2 0	1 11	3 2	3 3	3 2	4 2	4 3	4 3
8 17 6 ,,	2 0	2 1	2 0	3 3	3 4	3 3	4 2	4 3	4 3
9 0 0 ,,	2 0	2 1	2 0	3 4	3 5	3 4	4 3	4 4	4 4
9 2 6 ,,	2 0	2 1	2 0	3 4	3 5	3 4	4 4	4 5	4 5
9 5 0 ,,	2 1	2 2	2 1	3 5	3 6	3 5	4 5	4 6	4 6
9 7 6 ,,	2 1	2 2	2 1	3 5	3 6	3 5	4 5	4 6	4 6
9 10 0 ,,	2 1	2 2	2 1	3 6	3 7	3 6	4 6	4 7	4 7
9 12 6 ,,	2 2	2 3	2 2	3 6	3 7	3 6	4 7	4 8	4 8
9 15 0 ,,	2 2	2 3	2 2	3 7	3 8	3 7	4 7	4 8	4 8
9 17 6 ,,	2 2	2 4	2 2	3 7	3 8	3 7	4 8	4 9	4 9
10 0 0	2 2	2 4	2 2	3 8	3 9	3 8	4 9	4 10	4 10

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes 5. 6, and 7 inches diameter, at Rates from £4 to £10 per Ton. (Calculated to the nearest Penny.)

Diameter in Inches.	5.			6.			7.		
Class of Joint.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	77	79	78	91	93	92	121	124	123
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	2 9	2 10	2 9	3 3	3 4	3 3	4 4	4 5	4 5
4 2 6 "	2 10	2 11	2 10	3 4	3 5	3 5	4 5	4 7	4 6
4 5 0 "	2 11	3 0	3 0	3 5	3 6	3 6	4 7	4 8	4 8
4 7 6 "	3 0	3 1	3 1	3 6	3 7	3 7	4 9	4 10	4 10
4 10 0 "	3 1	3 2	3 2	3 8	3 9	3 8	4 10	5 0	4 11
4 12 6 "	3 2	3 3	3 3	3 9	3 10	3 10	5 0	5 1	5 1
4 15 0 "	3 3	3 4	3 4	3 10	3 11	3 11	5 2	5 3	5 3
4 17 6 "	3 4	3 5	3 5	4 0	4 1	4 0	5 4	5 5	5 4
5 0 0 "	3 5	3 6	3 6	4 1	4 2	4 1	5 5	5 6	5 6
5 2 6 "	3 6	3 7	3 7	4 2	4 3	4 3	5 6	5 8	5 8
5 5 0 "	3 7	3 8	3 8	4 3	4 4	4 4	5 8	5 10	5 9
5 7 6 "	3 8	3 9	3 9	4 4	4 5	4 5	5 10	5 11	5 11
5 10 0 "	3 9	3 10	3 10	4 6	4 7	4 6	5 11	6 1	6 0
5 12 6 "	3 10	4 0	3 11	4 7	4 8	4 7	6 1	6 3	6 2
5 15 0 "	3 11	4 1	4 0	4 8	4 9	4 9	6 2	6 4	6 4
5 17 6 "	4 0	4 2	4 1	4 9	4 11	4 10	6 4	6 6	6 5
6 0 0 "	4 1	4 3	4 2	4 10	5 0	4 11	6 6	6 8	6 7
6 2 6 "	4 2	4 4	4 3	5 0	5 1	5 0	6 7	6 9	6 9
6 5 0 "	4 3	4 5	4 4	5 1	5 2	5 2	6 9	6 11	6 10
6 7 6 "	4 4	4 6	4 5	5 2	5 3	5 3	6 11	7 1	7 0
6 10 0 "	4 6	4 7	4 6	5 3	5 5	5 4	7 0	7 2	7 2
6 12 6 "	4 7	4 8	4 7	5 4	5 6	5 5	7 2	7 4	7 3
6 15 0 "	4 8	4 9	4 8	5 6	5 7	5 7	7 4	7 6	7 5
6 17 6 "	4 9	4 10	4 9	5 7	5 9	5 8	7 5	7 7	7 7
7 0 0 "	4 10	4 11	4 10	5 8	5 10	5 9	7 7	7 9	7 8
7 2 6 "	4 11	5 0	5 0	5 9	5 11	5 10	7 8	7 11	7 10
7 5 0 "	5 0	5 1	5 1	5 11	6 0	5 11	7 10	8 0	8 0
7 7 6 "	5 1	5 2	5 2	6 0	6 1	6 1	8 0	8 2	8 1
7 10 0 "	5 2	5 3	5 3	6 1	6 3	6 2	8 1	8 4	8 3
7 12 6 "	5 3	5 5	5 4	6 2	6 4	6 3	8 3	8 5	8 4
7 15 0 "	5 4	5 6	5 5	6 3	6 5	6 4	8 4	8 7	8 6
7 17 6 "	5 5	5 7	5 6	6 5	6 6	6 6	8 6	8 9	8 8
8 0 0 "	5 6	5 8	5 7	6 6	6 8	6 7	8 8	8 10	8 9
8 2 6 "	5 7	5 9	5 8	6 7	6 9	6 8	8 9	9 0	8 11
8 5 0 "	5 8	5 10	5 9	6 8	6 10	6 9	8 11	9 2	9 1
8 7 6 "	5 9	5 11	5 10	6 10	6 11	6 10	9 1	9 3	9 2
8 10 0 "	5 10	6 0	5 11	6 11	7 0	7 0	9 2	9 5	9 4
8 12 6 "	5 11	6 1	6 0	7 0	7 2	7 1	9 4	9 7	9 6
8 15 0 "	6 0	6 2	6 1	7 1	7 3	7 2	9 5	9 8	9 7
8 17 6 "	6 1	6 3	6 2	7 3	7 4	7 3	9 7	9 10	9 9
9 0 0 "	6 2	6 4	6 3	7 4	7 6	7 5	9 9	10 0	9 10
9 2 6 "	6 3	6 5	6 4	7 5	7 7	7 6	9 10	10 1	10 0
9 5 0 "	6 4	6 6	6 5	7 6	7 8	7 7	10 0	10 3	10 2
9 7 6 "	6 5	6 7	6 6	7 7	7 9	7 8	10 2	10 5	10 4
9 10 0 "	6 6	6 8	6 7	7 9	7 10	7 10	10 3	10 6	10 5
9 12 6 "	6 7	6 9	6 8	7 10	8 0	7 11	10 5	10 8	10 7
9 15 0 "	6 8	6 10	6 9	7 11	8 1	8 0	10 6	10 10	10 8
9 17 6 "	6 9	6 11	6 11	8 0	8 2	8 1	10 8	10 11	10 10
10 0 0 "	6 11	7 1	7 0	8 2	8 4	8 3	10 10	11 1	11 0

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes 8, 9, *and* 10 *inches diameter, at Rates from* £4 *to* £10 *per Ton.* (*Calculated to the nearest Penny.*)

Diameter in Inches.	8.			9.			10.		
Class of Joint.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per Yard in lbs.	137	140	139	153	157	155	192	196	194
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	4 11	5 0	5 0	5 6	5 7	5 6	6 10	7 0	6 11
4 2 6 ”	5 1	5 2	5 1	5 8	5 9	5 9	7 1	7 3	7 2
4 5 0 ”	5 2	5 4	5 3	5 10	6 0	5 11	7 3	7 5	7 4
4 7 6 ”	5 4	5 6	5 5	6 0	6 2	6 1	7 6	7 8	7 7
4 10 0 ”	5 6	5 8	5 7	6 2	6 4	6 3	7 9	7 11	7 10
4 12 6 ”	5 8	5 9	5 9	6 4	6 6	6 5	7 11	8 1	8 0
4 15 0 ”	5 10	5 11	5 11	6 6	6 8	6 7	8 2	8 4	8 3
4 17 6 ”	6 0	6 1	6 1	6 8	6 10	6 9	8 4	8 6	8 5
5 0 0 ”	6 1	6 3	6 2	6 10	7 0	6 11	8 7	8 9	8 8
5 2 6 ”	6 3	6 5	6 4	7 0	7 2	7 1	8 9	9 0	8 11
5 5 0 ”	6 5	6 7	6 6	7 2	7 4	7 3	9 0	9 2	9 1
5 7 6 ”	6 7	6 9	6 8	7 4	7 6	7 5	9 3	9 5	9 4
5 10 0 ”	6 8	6 11	6 10	7 6	7 9	7 7	9 5	9 8	9 6
5 12 6 ”	6 11	7 0	7 0	7 8	7 11	7 9	9 8	9 10	9 9
5 15 0 ”	7 0	7 2	7 2	7 10	8 1	7 11	9 10	10 1	10 0
5 17 6 ”	7 2	7 4	7 3	8 0	8 3	8 2	10 1	10 3	10 2
6 0 0 ”	7 4	7 6	7 5	8 2	8 5	8 4	10 3	10 6	10 5
6 2 6 ”	7 6	7 8	7 7	8 4	8 7	8 6	10 6	10 9	10 7
6 5 0 ”	7 8	7 10	7 9	8 6	8 9	8 8	10 9	10 11	10 10
6 7 6 ”	7 10	8 0	7 11	8 8	8 11	8 10	10 11	11 2	11 1
6 10 0 ”	7 11	8 2	8 1	8 10	9 1	9 0	11 2	11 5	11 3
6 12 6 ”	8 1	8 3	8 3	9 1	9 3	9 2	11 4	11 7	11 6
6 15 0 ”	8 3	8 5	8 5	9 3	9 6	9 4	11 7	11 10	11 8
6 17 6 ”	8 5	8 7	8 6	9 5	9 8	9 6	11 9	12 0	11 11
7 0 0 ”	8 7	8 9	8 8	9 7	9 10	9 8	12 0	12 3	12 1
7 2 6 ”	8 9	8 11	8 10	9 9	10 0	9 10	12 3	12 6	12 4
7 5 0 ”	8 10	9 1	9 0	9 11	10 2	10 0	12 5	12 8	12 6
7 7 6 ”	9 0	9 3	9 2	10 1	10 4	10 2	12 8	12 11	12 9
7 10 0 ”	9 2	9 5	9 4	10 3	10 6	10 5	12 10	13 2	13 0
7 12 6 ”	9 4	9 6	9 6	10 5	10 8	10 7	13 1	13 4	13 2
7 15 0 ”	9 6	9 8	9 7	10 7	10 10	10 9	13 4	13 7	13 5
7 17 6 ”	9 8	9 10	9 9	10 9	11 0	10 11	13 6	13 9	13 7
8 0 0 ”	9 9	10 0	9 11	10 11	11 3	11 1	13 9	14 0	13 10
8 2 6 ”	9 11	10 2	10 1	11 1	11 5	11 3	13 11	14 3	14 0
8 5 0 ”	10 1	10 4	10 3	11 3	11 7	11 5	14 2	14 5	14 3
8 7 6 ”	10 3	10 6	10 5	11 5	11 9	11 7	14 4	14 8	14 6
8 10 0 ”	10 5	10 8	10 7	11 7	11 11	11 9	14 7	14 11	14 8
8 12 6 ”	10 7	10 9	10 8	11 9	12 1	11 11	14 9	15 1	14 11
8 15 0 ”	10 8	10 11	10 10	11 11	12 3	12 1	15 0	15 4	15 2
8 17 6 ”	10 10	11 1	11 0	12 1	12 5	12 3	15 2	15 6	15 4
9 0 0 ”	11 0	11 3	11 2	12 3	12 7	12 5	15 5	15 9	15 7
9 2 6 ”	11 2	11 5	11 4	12 5	12 9	12 8	15 7	16 0	15 9
9 5 0 ”	11 4	11 7	11 6	12 8	13 0	12 10	15 10	16 2	16 0
9 7 6 ”	11 6	11 9	11 8	12 10	13 2	13 0	16 0	16 5	16 2
9 10 0 ”	11 7	11 11	11 9	13 0	13 4	13 2	16 3	16 8	16 5
9 12 6 ”	11 9	12 0	11 11	13 2	13 6	13 4	16 5	16 10	16 8
9 15 0 ”	11 11	12 2	12 1	13 4	13 8	13 6	16 8	17 1	16 10
9 17 6 ”	12 1	12 4	12 3	13 6	13 10	13 8	16 10	17 3	17 1
10 0 0 ”	12 3	12 6	12 5	13 8	14 0	13 10	17 2	17 6	17 3

TABLE

Giving Weight and Cost per yard of Cast-Iron Main Gas Pipes, **11, 12,** *and* **13** *inches diameter, at Rates from £4 to £10 per Ton.* (*Calculated to the nearest Penny.*)

Diameter in Inches.	11.			12.			13.		
Class of Joint.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	210	215	212	249	253	251	269	273	271
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	7 6	7 8	7 7	8 11	9 0	9 0	9 7	9 9	9 8
4 2 6 "	7 9	7 11	7 10	9 2	9 4	9 3	9 11	10 1	10 0
4 5 0 "	8 0	8 2	8 0	9 5	9 7	9 6	10 3	10 4	10 3
4 7 6 "	8 2	8 5	8 3	9 9	9 11	9 10	10 6	10 8	10 7
4 10 0 "	8 5	8 8	8 6	10 0	10 2	10 1	10 10	11 0	10 11
4 12 6 "	8 8	8 11	8 9	10 3	10 5	10 4	11 1	11 3	11 2
4 15 0 "	8 11	9 1	9 0	10 6	10 9	10 8	11 5	11 7	11 6
4 17 6 "	9 2	9 4	9 3	10 10	11 0	10 11	11 9	11 11	11 10
5 0 0 "	9 4	9 7	9 5	11 1	11 4	11 3	12 0	12 2	12 1
5 2 6 "	9 7	9 10	9 8	11 4	11 7	11 6	12 4	12 6	12 5
5 5 0 "	9 10	10 1	9 11	11 7	11 10	11 9	12 7	12 10	12 8
5 7 6 "	10 1	10 4	10 2	11 11	12 2	12 0	12 11	13 1	13 0
5 10 0 "	10 4	10 7	10 5	12 2	12 5	12 4	13 3	13 5	13 4
5 12 6 "	10 7	10 10	10 8	12 5	12 8	12 7	13 6	13 9	13 7
5 15 0 "	10 10	11 1	10 10	12 9	13 0	12 11	13 10	14 0	13 11
5 17 6 "	11 0	11 3	11 1	13 1	13 3	13 2	14 1	14 4	14 3
6 0 0 "	11 3	11 6	11 4	13 4	13 7	13 5	14 5	14 8	14 6
6 2 6 "	11 6	11 9	11 7	13 7	13 10	13 9	14 9	14 11	14 10
6 5 0 "	11 9	12 0	11 10	13 11	14 1	14 0	15 0	15 3	15 2
6 7 6 "	11 11	12 3	12 1	14 2	14 5	14 3	15 4	15 6	15 5
6 10 0 "	12 3	12 6	12 4	14 5	14 8	14 7	15 7	15 10	15 9
6 12 6 "	12 5	12 8	12 6	14 9	15 0	14 10	15 11	16 2	16 0
6 15 0 "	12 8	13 0	12 9	15 0	15 3	15 2	16 3	16 5	16 4
6 17 6 "	12 11	13 2	13 0	15 3	15 6	15 5	16 6	16 9	16 8
7 0 0 "	13 2	13 5	13 3	15 7	15 10	15 8	16 10	17 1	16 11
7 2 6 "	13 5	13 8	13 6	15 10	16 1	16 0	17 1	17 4	17 3
7 5 0 "	13 7	13 10	13 9	16 1	16 5	16 3	17 5	17 8	17 7
7 7 6 "	13 10	14 2	14 0	16 5	16 8	16 6	17 9	18 0	17 10
7 10 0 "	14 2	14 5	14 2	16 8	16 11	16 10	18 0	18 3	18 2
7 12 6 "	14 4	14 8	14 5	16 11	17 3	17 1	18 4	18 7	18 5
7 15 0 "	14 6	14 11	14 8	17 3	17 6	17 4	18 7	18 11	18 9
7 17 6 "	14 9	15 1	14 11	17 6	17 9	17 8	18 11	19 2	19 1
8 0 0 "	15 0	15 4	15 2	17 10	18 1	17 11	19 3	19 6	19 4
8 2 6 "	15 3	15 7	15 4	18 1	18 4	18 2	19 6	19 10	19 8
8 5 0 "	15 6	15 10	15 7	18 4	18 7	18 5	19 10	20 1	20 0
8 7 6 "	15 8	16 1	15 10	18 8	18 11	18 9	20 1	20 5	20 3
8 10 0 "	15 11	16 4	16 1	18 11	19 2	19 0	20 5	20 9	20 7
8 12 6 "	16 2	16 7	16 4	19 2	19 6	19 4	20 9	21 0	20 10
8 15 0 "	16 5	16 10	16 7	19 6	19 9	19 7	21 0	21 4	21 2
8 17 6 "	16 8	17 0	16 9	19 9	20 1	19 11	21 4	21 8	21 6
9 0 0 "	16 10	17 3	17 0	20 0	20 4	20 2	21 7	21 11	21 9
9 2 6 "	17 1	17 6	17 3	20 4	20 7	20 5	21 11	22 3	22 1
9 5 0 "	17 4	17 9	17 6	20 7	20 11	20 9	22 3	22 7	22 5
9 7 6 "	17 7	18 0	17 9	20 10	21 2	21 0	22 6	22 10	22 8
9 10 0 "	17 10	18 3	18 0	21 2	21 6	21 4	22 10	23 2	23 0
9 12 6 "	18 1	18 6	18 3	21 5	21 9	21 7	23 1	23 6	23 4
9 15 0 "	18 3	18 9	18 6	21 8	22 0	21 10	23 5	23 9	23 7
9 17 6 "	18 6	19 0	18 8	22 0	22 4	22 2	23 9	24 1	23 11
10 0 0 "	18 9	19 2	18 11	22 3	22 7	22 5	24 0	24 5	24 2

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 14, 15, *and* 16 *inches diameter, at Rates from* £4 *to* £10 *per Ton.* (*Calculated to the nearest Penny.*)

Diameter in inches.	14.						15.						16.					
Class of Joint.	Open.		T. & B.		Flnge.		Open.		T. & B.		Flnge.		Open.		T. & B.		Flnge.	
Weight per yard in lbs.	289		293		291		309		314		311		363		368		366	
Cost per yard at	s.	d.	s.	d.	s.	d.	s.	d.	s.	d	s.	d.	s.	d.	s.	d.	s.	d.
£4 0 0 per ton.	10	4	10	6	10	5	11	0	11	3	11	1	13	0	13	2	13	1
4 2 6 ,,	10	8	10	9	10	9	11	5	11	7	11	5	13	4	13	7	13	6
4 5 0 ,,	11	0	11	1	11	1	11	9	11	11	11	10	13	9	14	0	13	11
4 7 6 ,,	11	3	11	5	11	4	12	1	12	3	12	2	14	2	14	5	14	4
4 10 0 ,,	11	7	11	9	11	8	12	5	12	7	12	6	14	7	14	9	14	8
4 12 6 ,,	11	11	12	1	12	0	12	9	13	0	12	10	15	0	15	2	15	1
4 15 0 ,,	12	3	12	5	12	4	13	1	13	4	13	2	15	5	15	7	15	6
4 17 6 ,,	12	7	12	9	12	8	13	5	13	8	13	6	15	10	16	0	15	11
5 0 0 ,,	12	11	13	1	13	0	13	10	14	0	13	11	16	2	16	5	16	4
5 2 6 ,,	13	3	13	5	13	4	14	2	14	4	14	3	16	7	16	10	16	9
5 5 0 ,,	13	7	13	9	13	8	14	6	14	9	14	7	17	0	17	3	17	2
5 7 6 ,,	13	10	14	1	14	0	14	10	15	1	14	11	17	5	17	8	17	7
5 10 0 ,,	14	2	14	5	14	3	15	2	15	5	15	3	17	10	18	1	18	0
5 12 6 ,,	14	6	14	9	14	7	15	6	15	9	15	7	18	3	18	6	18	5
5 15 0 ,,	14	10	15	0	14	11	15	10	16	1	15	11	18	8	18	11	18	9
5 17 6 ,,	15	2	15	4	15	3	16	3	16	6	16	4	19	0	19	4	19	2
6 0 0 ,,	15	6	15	8	15	7	16	7	16	10	16	8	19	5	19	8	19	7
6 2 6 ,,	15	10	16	0	15	11	16	11	17	2	17	0	19	10	20	2	20	0
6 5 0 ,,	16	1	16	4	16	3	17	3	17	6	17	4	20	3	20	6	20	5
6 7 6 ,,	16	5	16	8	16	7	17	7	17	10	17	8	20	8	20	11	20	10
6 10 0 ,,	16	9	17	0	16	11	17	11	18	3	18	0	21	1	21	4	21	3
6 12 6 ,,	17	1	17	4	17	3	18	3	18	7	18	5	21	6	21	9	21	8
6 15 0 ,,	17	5	17	8	17	6	18	7	18	11	18	9	21	10	22	2	22	1
6 17 6 ,,	17	9	18	0	17	10	19	0	19	3	19	1	22	3	22	7	22	6
7 0 0 ,,	18	1	18	4	18	2	19	4	19	7	19	5	22	8	23	0	22	10
7 2 6 ,,	18	5	18	8	18	6	19	8	20	0	19	9	23	1	23	5	23	3
7 5 0 ,,	18	8	18	11	18	10	20	0	20	4	20	1	23	6	23	10	23	8
7 7 6 ,,	19	0	19	4	19	2	20	4	20	8	20	6	23	11	24	3	24	1
7 10 0 ,,	19	4	19	7	19	6	20	8	21	0	20	10	24	4	24	8	24	6
7 12 6 ,,	19	8	19	11	19	10	21	0	21	5	21	2	24	9	25	1	24	11
7 15 0 ,,	20	0	20	3	20	2	21	4	21	9	21	6	25	1	25	5	25	4
7 17 6 ,,	20	4	20	7	20	6	21	9	22	1	21	10	25	6	25	11	25	9
8 0 0 ,,	20	8	20	11	20	9	22	1	22	5	22	2	25	11	26	3	26	2
8 2 6 ,,	21	0	21	3	21	1	22	5	22	9	22	7	26	4	26	8	26	7
8 5 0 ,,	21	3	21	7	21	5	22	9	23	2	22	11	26	9	27	1	26	11
8 7 6 ,,	21	7	21	11	21	9	23	1	23	6	23	3	27	2	27	6	27	4
8 10 0 ,,	21	11	22	3	22	1	23	5	23	10	23	7	27	6	27	11	27	9
8 12 6 ,,	22	3	22	7	22	5	23	10	24	2	23	11	27	11	28	4	28	2
8 15 0 ,,	22	7	22	11	22	9	24	2	24	6	24	3	28	4	28	9	28	7
8 17 6 ,,	22	11	23	3	23	1	24	6	24	10	24	8	28	9	29	2	29	0
9 0 0	23	3	23	6	23	4	24	10	25	3	25	0	29	2	29	7	29	5
9 2 6 ,,	23	7	23	10	23	9	25	2	25	7	25	4	29	7	30	0	29	10
9 5 0 ,,	23	10	24	2	24	0	25	6	25	11	25	8	30	0	30	5	30	3
9 7 6 ,,	24	2	24	6	24	4	25	10	26	3	26	0	30	5	30	10	30	8
9 10 0 ,,	24	6	24	10	24	8	26	2	26	7	26	4	30	9	31	2	31	0
9 12 6 ,,	24	10	25	2	25	0	26	7	27	0	26	9	31	2	31	8	31	5
9 15 0 ,,	25	2	25	6	25	4	26	11	27	4	27	1	31	7	32	0	31	10
9 17 6 ,,	25	6	25	10	25	8	27	3	27	8	27	5	32	0	32	5	32	3
10 0 0 ,,	25	10	26	2	26	0	27	7	28	0	27	9	32	5	32	10	32	8

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 17, 18, *and* 19 *inches diameter, at Rates from* £4 *to* £10 *per Ton.* (*Calculated to the nearest Penny.*)

Diameter in Inches.	17.						18.						19.					
Class of Joint.	Open.		T. & B.		Flnge		Open.		T. & B.		Flnge.		Open.		T. & B.		Flnge.	
Weight per yard in lbs.	384		390		387		406		412		409		468		475		472	
Cost per yard at	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
£4 0 0 per ton.	13	8	13	11	13	10	14	6	14	8	14	7	16	8	16	11	16	10
4 2 6 ,,	14	2	14	4	14	3	14	11	15	2	15	1	17	3	17	6	17	5
4 5 0 ,,	14	7	14	9	14	8	15	5	15	7	15	6	17	9	18	0	17	11
4 7 6 ,,	15	0	15	3	15	1	15	10	16	1	16	0	18	3	18	7	18	5
4 10 0 ,,	15	5	15	8	15	6	16	4	16	7	16	5	18	10	19	1	18	11
4 12 6 ,,	15	10	16	1	15	11	16	9	17	0	16	11	19	4	19	7	19	6
4 15 0 ,,	16	3	16	6	16	5	17	2	17	6	17	4	19	10	20	2	20	0
4 17 6 ,,	16	9	17	0	16	9	17	8	17	11	17	10	20	4	20	8	20	7
5 0 0 ,,	17	2	17	5	17	3	18	1	18	5	18	3	20	11	21	2	21	1
5 2 6 ,,	17	7	17	10	17	9	18	7	18	10	18	9	21	5	21	9	21	7
5 5 0 ,,	18	0	18	3	18	2	19	0	19	4	19	2	21	11	22	3	22	1
5 7 6 ,,	18	5	18	9	18	7	19	6	19	9	19	8	22	6	22	10	22	8
5 10 0 ,,	18	10	19	2	19	0	19	11	20	3	20	1	23	0	23	4	23	2
5 12 6 ,,	19	3	19	7	19	5	20	5	20	8	20	6	23	6	23	10	23	8
5 15 0 ,,	19	8	20	0	19	10	20	10	21	2	21	0	24	0	24	5	24	3
5 17 6 ,,	20	2	20	5	20	4	21	4	21	7	21	5	24	7	24	11	24	9
6 0 0 ,,	20	7	20	11	20	9	21	9	22	1	21	11	25	1	25	5	25	3
6 2 6 ,,	21	0	21	4	21	2	22	2	22	6	22	4	25	7	26	0	25	10
6 5 0 ,,	21	5	21	9	21	7	22	8	23	0	22	10	26	1	26	6	26	4
6 7 6 ,,	21	10	22	2	22	0	23	1	23	5	23	3	26	8	27	0	26	10
6 10 0 ,,	22	3	22	7	22	5	23	7	23	11	23	9	27	2	27	7	27	5
6 12 6 ,,	22	9	23	1	22	11	24	0	24	4	24	2	27	8	28	1	27	11
6 15 0 ,,	23	2	23	6	23	4	24	5	24	10	24	8	28	2	28	7	28	5
6 17 6 ,,	23	7	23	11	23	9	24	11	25	3	25	1	28	7	29	2	29	0
7 0 0 ,,	24	0	24	4	24	2	25	4	25	9	25	7	29	3	29	8	29	6
7 2 6 ,,	24	5	24	10	24	7	25	10	26	3	26	0	29	9	30	3	30	0
7 5 0 ,,	24	10	25	3	25	0	26	3	26	8	26	6	30	3	30	9	30	7
7 7 6 ,,	25	3	25	8	25	6	26	9	27	2	26	11	30	10	31	3	31	1
7 10 0 ,,	25	8	26	1	25	11	27	2	27	7	27	5	31	4	31	10	31	8
7 12 6 ,,	26	2	26	7	26	4	27	8	28	1	27	10	31	10	32	4	32	2
7 15 0 ,,	26	7	27	0	26	9	28	1	28	6	28	3	32	4	32	10	32	8
7 17 6 ,,	27	0	27	5	27	2	28	7	29	0	28	9	32	11	33	5	33	2
8 0 0 ,,	27	5	27	10	27	8	29	0	29	5	29	2	33	5	33	11	33	8
8 2 6 ,,	27	10	28	4	28	1	29	5	29	11	29	8	33	11	34	6	34	3
8 5 0 ,,	28	3	28	9	28	6	29	11	30	4	30	1	34	6	35	0	34	9
8 7 6 ,,	28	8	29	2	28	11	30	4	30	10	30	7	35	0	35	6	35	4
8 10 0 ,,	29	2	29	7	29	4	30	10	31	3	31	0	35	6	36	0	35	10
8 12 6 ,,	29	7	30	0	29	10	31	3	31	8	31	6	36	1	36	7	36	4
8 15 0 ,,	30	0	30	5	30	3	31	8	32	2	31	11	36	7	37	1	36	10
8 17 6 ,,	30	5	30	11	30	8	32	2	32	8	32	5	37	1	37	8	37	5
9 0 0 ,,	30	10	31	4	31	1	32	7	33	1	32	10	37	7	38	2	37	11
9 2 6 ,,	31	3	31	9	31	6	33	1	33	7	33	4	38	2	38	8	38	5
9 5 0 ,,	31	8	32	2	31	11	33	6	34	0	33	9	38	8	39	3	39	0
9 7 6 ,,	32	1	32	8	32	5	34	0	34	6	34	3	39	2	39	9	39	6
9 10 0 ,,	32	7	33	1	32	10	34	5	34	11	34	8	39	8	40	3	40	0
9 12 6 ,,	33	0	33	6	33	3	34	11	35	5	35	2	40	3	40	10	40	7
9 15 0 ,,	33	5	33	11	33	8	35	4	35	10	35	7	40	9	41	4	41	1
9 17 6 ,,	33	10	34	5	34	1	35	10	36	4	36	1	41	3	41	11	41	7
10 0 0 ,,	34	3	34	10	34	7	36	3	36	9	36	6	41	9	42	5	42	2

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, 20, 21, *and* 22 *inches diameter, at Rates from* £4 *to* £10 *per Ton.* (*Calculated to the nearest Penny.*)

Diameter in Inches.	20.			21.			22.		
Class of Joint.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	492	500	496	516	524	520	589	595	590
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	17 7	17 10	17 8	18 5	18 8	18 7	20 11	21 8	21 1
4 2 6 "	18 1	18 5	18 3	19 0	19 4	19 2	21 7	21 11	21 9
4 5 0 "	18 8	19 0	18 10	19 7	19 11	19 9	22 3	22 7	22 5
4 7 6 "	19 3	19 6	19 5	20 2	20 6	20 4	22 11	23 3	23 1
4 10 0 "	19 9	20 0	19 11	20 9	21 1	20 11	23 6	23 11	23 8
4 12 6 "	20 4	20 8	20 6	21 4	21 8	21 6	24 2	24 7	24 4
4 15 0 "	20 10	21 2	21 0	21 10	22 3	22 1	24 10	25 3	25 0
4 17 6 "	21 5	21 9	21 7	22 6	22 10	22 8	25 6	25 11	25 8
5 0 0 "	21 11	22 4	22 2	23 0	23 5	23 2	26 2	26 7	26 4
5 2 6 "	22 6	22 11	22 8	23 7	24 0	23 9	26 10	27 3	27 0
5 5 0 "	23 1	23 5	23 3	24 2	24 7	24 4	27 5	27 11	27 8
5 7 6 "	23 7	24 0	23 10	24 9	25 2	25 0	28 1	28 7	28 4
5 10 0 "	24 2	24 7	24 4	25 4	25 9	25 6	28 9	29 3	29 0
5 12 6 "	24 9	25 1	24 11	25 11	26 4	26 1	29 5	29 11	29 8
5 15 0 "	25 3	25 8	25 5	26 6	26 11	26 8	30 1	30 6	30 3
5 17 6 "	25 10	26 3	26 0	27 1	27 6	27 3	30 9	31 3	30 11
6 0 0 "	26 4	26 9	26 7	27 8	28 1	27 10	31 5	31 10	31 7
6 2 6 "	26 11	27 4	27 2	28 3	28 8	28 5	32 0	32 6	32 3
6 5 0 "	27 5	27 11	27 8	28 0	29 3	29 0	32 8	33 2	32 11
6 7 6 "	28 0	28 6	28 3	23 4	29 10	29 7	33 4	33 10	33 7
6 10 0 "	28 7	29 0	28 9	29 11	30 5	30 2	34 0	34 6	34 3
6 12 6 "	29 1	29 7	29 4	30 6	31 0	30 9	34 8	35 2	34 11
6 15 0 "	29 8	30 1	29 11	31 1	31 7	31 4	35 4	35 10	35 7
6 17 6 "	30 2	30 8	30 5	31 8	32 2	31 11	36 0	36 6	36 3
7 0 0 "	30 9	31 3	31 0	32 3	32 9	32 6	36 7	37 2	36 10
7 2 6 "	31 4	31 10	31 7	32 10	33 4	33 1	37 3	37 10	37 6
7 5 0 "	31 10	32 4	32 1	33 5	33 11	33 8	37 11	38 6	38 2
7 7 6 "	32 5	32 11	32 8	34 0	34 6	34 3	38 7	39 2	38 10
7 10 0 "	32 11	33 6	33 2	34 7	35 1	34 10	39 3	39 10	39 6
7 12 6 "	33 6	34 0	33 9	35 2	35 8	35 5	39 11	40 6	40 2
7 15 0 "	34 0	34 7	34 4	35 8	36 3	36 0	40 6	41 2	40 10
7 17 6 "	34 7	35 2	34 11	36 3	36 10	36 7	41 2	41 10	41 6
8 0 0 "	35 2	35 8	35 5	36 10	37 5	37 2	41 10	42 6	42 2
8 2 6 "	35 8	36 3	36 0	37 5	38 0	37 9	42 6	43 2	42 10
8 5 0 "	36 3	36 10	36 6	38 0	38 7	38 4	43 2	43 10	43 5
8 7 6 "	36 9	37 5	37 1	38 7	39 2	38 11	43 10	44 6	44 1
8 10 0 "	37 4	37 11	37 8	39 2	39 9	39 5	44 6	45 2	44 9
8 12 6 "	37 11	38 6	28 2	39 9	40 4	40 0	45 2	45 10	45 5
8 15 0 "	38 5	39 1	38 9	40 4	40 11	40 7	45 9	46 6	46 1
8 17 6 "	39 0	39 7	39 4	40 11	41 6	41 2	46 5	47 2	46 9
9 0 0 "	39 6	40 2	39 10	41 5	42 1	41 9	47 1	47 10	47 5
9 2 6 "	40 1	40 9	40 5	42 0	42 8	42 4	47 9	48 6	48 1
9 5 0 "	40 7	41 3	40 11	42 7	43 3	42 11	48 5	49 2	48 9
9 7 6 "	41 2	41 10	41 6	43 2	43 10	43 6	49 1	49 10	49 5
9 10 0 "	41 9	42 5	42 1	43 9	44 5	44 1	49 8	50 5	50 0
9 12 6 "	42 3	43 0	42 8	44 4	45 0	44 8	50 4	51 1	50 8
9 15 0 "	42 10	43 6	43 2	44 11	45 7	45 3	51 0	51 9	51 4
9 17 6 "	43 5	44 1	43 9	45 6	46 2	45 10	51 8	52 5	52 0
10 0 0 "	43 11	44 8	44 3	46 1	46 9	46 5	52 4	53 1	52 8

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes, **23, 24** *and* **30** *inches diameter, at Rates from* **£4** *to* **£10** *per Ton. (Calculated to the nearest Penny.)*

Diameter in Inches.	23.						24.						30.					
Class of Joint.	Open.		T. & B.		Flnge.		Open.		T. & B.		Flnge.		Open.		T. & B.		Flnge.	
Weight per yard in lbs.	611		621		616		688		699		693		980		995		987	
Cost per yard at	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
£4 0 0 per ton.	21	10	22	2	22	0	24	7	24	11	24	9	35	0	35	6	35	3
4 2 6 "	22	6	22	10	22	8	25	4	25	9	25	6	36	1	36	8	36	4
4 5 0 "	23	2	23	7	23	4	26	1	26	6	26	3	37	2	37	9	37	5
4 7 6 "	23	10	24	3	24	1	26	11	27	4	27	1	38	3	38	10	38	7
4 10 0 "	24	6	24	11	24	9	27	8	28	1	27	10	39	4	40	0	39	8
4 12 6 "	25	3	25	8	25	5	28	5	28	10	28	7	40	6	41	1	40	9
4 15 0 "	25	11	26	4	26	1	29	2	29	8	29	5	41	7	42	2	41	10
4 17 6 "	26	7	27	0	26	10	29	11	30	5	30	2	42	8	43	4	43	0
5 0 0 "	27	3	27	9	27	6	30	8	31	2	30	11	43	9	44	5	44	1
5 2 6 "	28	0	28	5	28	2	31	6	32	0	31	9	44	10	45	6	45	2
5 5 0 "	28	8	29	1	28	10	32	3	32	9	32	6	45	11	46	8	46	3
5 7 6 "	29	4	29	10	29	7	33	0	33	7	33	3	47	0	47	9	47	4
5 10 0 "	30	0	30	6	30	3	33	9	34	4	34	0	48	1	48	10	48	5
5 12 6 "	30	8	31	2	30	11	34	7	35	1	34	10	49	3	50	0	49	7
5 15 0 "	31	4	31	10	31	7	35	4	35	11	35	7	50	4	51	1	50	8
5 17 6 "	32	1	32	7	32	4	36	1	36	8	36	4	51	5	52	2	51	9
6 0 0 "	32	9	33	3	33	0	36	10	37	5	37	1	52	6	53	4	52	10
6 2 6 "	33	5	34	0	33	8	37	8	38	3	37	11	53	7	54	5	54	0
6 5 0 "	34	1	34	8	34	4	38	5	39	0	38	8	54	8	55	6	55	1
6 7 6 "	34	9	35	4	35	1	39	2	39	9	39	5	55	9	56	8	56	2
6 10 0 "	35	5	36	0	35	9	39	11	40	7	40	2	56	10	57	9	57	3
6 12 6 "	36	2	36	9	36	5	40	8	41	4	41	0	58	0	58	10	58	5
6 15 0 "	36	10	37	5	37	1	41	5	42	1	41	9	59	1	59	11	59	6
6 17 6 "	37	6	38	1	37	10	42	3	42	11	42	6	60	2	61	0	60	7
7 0 0 "	38	2	38	10	38	6	43	0	43	8	43	4	61	3	62	2	61	8
7 2 6 "	38	10	39	6	39	2	43	9	44	6	44	1	62	4	63	3	62	9
7 5 0 "	39	6	40	2	39	10	44	6	45	3	44	10	63	5	64	5	63	11
7 7 6 "	40	3	40	11	40	7	45	4	46	0	45	7	64	6	65	6	65	0
7 10 0 "	40	11	41	7	41	3	46	1	46	10	46	5	65	7	66	7	66	1
7 12 6 "	41	7	42	3	41	11	46	10	47	7	47	2	66	9	67	8	67	2
7 15 0 "	42	3	42	11	42	7	47	7	48	4	47	11	67	10	68	10	68	3
7 17 6 "	42	11	43	8	43	4	48	5	49	2	48	9	68	11	69	11	69	5
8 0 0 "	43	8	44	4	44	0	49	2	49	11	49	6	70	0	71	0	70	6
8 2 6 "	44	4	45	1	44	8	49	11	50	9	50	3	71	1	72	1	71	7
8 5 0 "	45	0	45	9	45	4	50	8	51	6	51	0	72	2	73	3	72	8
8 7 6 "	45	8	46	5	46	1	51	5	52	3	51	10	73	3	74	4	73	10
8 10 0 "	46	4	47	1	46	9	52	2	53	0	52	7	74	4	75	6	74	11
8 12 6 "	47	0	47	10	47	5	53	0	53	10	53	4	75	6	76	8	76	0
8 15 0 "	47	9	48	6	48	2	53	9	54	7	54	2	76	7	77	9	77	1
8 17 6 "	48	5	49	3	48	10	54	6	55	5	54	11	77	8	78	10	78	3
9 0 0 "	49	1	49	11	49	6	55	3	56	2	55	8	78	9	79	11	79	4
9 2 6 "	49	9	50	7	50	2	56	1	56	11	56	6	79	10	81	1	80	5
9 5 0 "	50	5	51	3	50	10	56	10	57	9	57	3	80	11	82	2	81	6
9 7 6 "	51	2	52	0	51	7	57	7	58	6	58	0	82	0	83	3	82	7
9 10 0 "	51	10	52	8	52	3	58	4	59	3	58	9	83	1	84	5	83	8
9 12 6 "	52	6	53	4	52	11	59	2	60	1	59	7	84	2	85	6	84	10
9 15 0 "	53	2	54	1	53	7	59	11	60	10	60	4	85	4	86	7	85	11
9 17 6 "	53	10	54	9	54	4	60	8	61	8	61	1	86	5	87	9	87	0
10 0 0 "	54	7	55	5	55	0	61	5	62	5	61	10	87	6	88	10	88	1

TABLE

Giving Weight and Cost per Yard of Cast-Iron Main Gas Pipes 36, 42, *and* 48 *inches diameter, at Rates from* £4 *to* £10 *per Ton.* (*Calculated to the nearest Penny.*)

Diameter in Inches.	36.			42.			48.		
Class of Joint.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.	Open.	T. & B.	Flnge.
Weight per yard in lbs.	1320	1341	1330	1621	1646	1638	1946	1976	1961
Cost per yard at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
£4 0 0 per ton.	47 2	47 11	47 6	57 11	58 9	58 4	69 6	70 7	70 0
4 2 6 ”	48 7	49 5	49 0	59 8	60 7	60 2	71 8	72 9	72 3
4 5 0 ”	50 1	50 11	50 5	61 6	62 5	61 11	73 10	75 0	74 5
4 7 6 ”	51 7	52 5	51 11	63 4	64 4	63 9	75 11	77 2	76 7
4 10 0 ”	53 0	53 10	53 5	65 1	66 2	65 7	78 2	79 5	78 9
4 12 6 ”	54 6	55 4	54 11	66 11	68 0	67 5	80 4	81 7	81 0
4 15 0 ”	56 0	56 10	56 5	68 9	69 10	69 3	82 6	83 10	83 2
4 17 6 ”	57 5	58 4	57 11	70 7	71 8	71 1	84 8	86 0	85 4
5 0 0 ”	58 11	59 10	59 4	72 4	73 6	72 11	86 10	88 2	87 6
5 2 6 ”	60 4	61 4	60 10	74 2	75 4	74 9	89 1	90 5	89 9
5 5 0 ”	61 10	62 10	62 4	76 0	77 2	76 6	91 3	92 7	91 11
5 7 6 ”	63 4	64 4	63 10	77 10	79 0	78 4	93 5	94 10	94 1
5 10 0 ”	64 10	65 10	65 4	79 7	80 10	80 2	95 7	97 0	96 3
5 12 6 ”	66 4	67 4	66 10	81 5	82 8	82 0	97 9	99 3	98 6
5 15 0 ”	67 9	68 10	68 3	83 3	84 6	83 10	99 11	101 5	100 8
5 17 6 ”	69 3	70 4	69 9	85 0	86 4	85 8	102 1	103 8	102 10
6 0 0 ”	70 8	71 10	71 3	86 10	88 2	87 6	104 3	105 10	105 1
6 2 6 ”	72 2	73 4	72 9	88 8	90 0	89 3	106 5	108 0	107 3
6 5 0 ”	73 8	74 10	74 2	90 5	91 10	91 1	108 7	110 3	109 5
6 7 6 ”	75 2	76 4	75 8	92 3	93 8	92 11	110 8	112 6	111 7
6 10 0 ”	76 7	77 10	77 2	94 1	95 6	94 9	112 11	114 8	113 10
6 12 6 ”	78 1	79 3	78 8	95 11	97 4	96 8	115 1	116 11	116 0
6 15 0 ”	79 7	80 10	80 2	97 8	99 2	98 5	117 3	119 1	118 2
6 17 6 ”	81 0	82 4	81 8	99 6	101 0	100 3	119 5	121 4	120 6
7 0 0 ”	82 6	83 10	83 1	101 4	102 10	102 1	121 7	123 6	122 4
7 2 6 ”	84 0	85 4	84 7	103 1	104 9	103 11	123 10	125 8	124 7
7 5 0 ”	85 5	86 10	86 1	104 11	106 6	105 8	126 0	127 11	126 19
7 7 6 ”	86 11	88 4	87 7	106 9	108 5	107 6	128 2	130 1	129 1
7 10 0 ”	88 5	89 9	89 1	108 6	110 3	109 4	130 4	132 4	131 2
7 12 6 ”	89 10	91 4	90 6	110 4	112 1	111 2	132 6	134 6	133 4
7 15 0 ”	91 4	92 9	92 0	112 2	113 11	113 0	134 8	136 9	135 3
7 17 6 ”	92 10	94 3	93 6	114 0	115 9	114 10	136 10	138 11	137 11
8 0 0 ”	94 3	95 9	95 0	115 9	117 7	116 8	139 0	141 2	140 1
8 2 6 ”	95 9	97 3	96 6	117 7	119 5	118 6	141 2	143 4	142 3
8 5 0 ”	97 3	98 9	97 11	119 5	121 3	120 3	143 4	145 7	144 5
8 7 6 ”	98 9	100 3	99 5	121 3	123 1	122 2	145 6	147 9	146 8
8 10 0 ”	100 2	101 9	100 11	123 0	124 11	123 11	147 8	149 11	148 10
8 12 6 ”	101 8	103 3	102 5	124 10	126 9	125 9	149 10	152 1	151 0
8 15 0 ”	103 1	104 9	103 11	126 8	128 7	127 7	152 0	154 4	153 2
8 17 6 ”	104 7	106 3	105 5	128 6	130 5	129 5	154 2	156 6	155 5
9 0 0 ”	106 1	107 9	106 10	130 3	132 3	131 3	156 4	158 9	157 7
9 2 6 ”	107 7	109 3	108 4	132 1	134 1	133 1	158 7	160 11	159 9
9 5 0 ”	109 0	110 9	109 10	133 10	135 11	134 10	160 8	163 2	161 11
9 7 6 ”	110 6	112 3	111 4	135 8	137 9	136 8	162 11	165 4	164 1
9 10 0 ”	111 11	113 9	112 10	137 6	139 7	138 6	165 1	167 7	166 4
9 12 6 ”	113 5	115 3	114 4	139 4	141 5	140 4	167 3	169 9	168 6
9 15 0 ”	114 11	116 9	115 9	141 1	143 3	142 2	169 5	172 0	170 8
9 17 6 ”	116 5	118 3	117 3	142 11	145 1	144 0	171 7	174 2	172 10
10 0 0 ”	117 10	119 9	118 9	144 9	146 11	145 10	173 9	176 5	175 1

TABLE *showing the Discharges of Gas in Cubic Feet per Hour. Specific Gravity* ·**420.** *Pressure,* **1** *inch.*
(*Clegg,* **4***th Ed., p.* **304.**)

Length of Pipes in Yards.	Diameter of Pipes in Inches.														
	2.	3.	4.	5.	6.	7.	8.	9.	10.	12.	14.	16.	18.	20.	22.
20	2,291	7,253	..	..	..	..	..	..	..	..	..	..	..	..	..
30	2,149	5,941	12,160	21,262	..	..	..	..	..	..	..	..	..	..	..
40	1,859	5,127	11,340	18,192	28,965	..	..	..	..	..	..	..	..	..	..
50	1,666	4,580	9,417	16,367	25,758	38,168	53,808	..	..	..	..	..	..	..	..
100	1,177	3,244	6,652	11,643	18,322	26,989	37,670	50,519	65,475	..	..	..	..	..	..
150	961	2,653	5,421	9,483	14,968	21,027	30,758	41,334	53,970	84,758	124,362	..	..	..	..
200	833	2,284	4,708	8,209	12,976	19,051	26,611	35,757	46,575	73,288	107,950	150,681	201,986	..	..
250	745	2,053	4,212	7,357	11,566	17,066	23,846	32,367	42,580	65,703	96,579	134,774	179,252	235,440	300,564
300	679	1,871	3,844	6,716	10,594	15,479	21,686	29,196	37,935	59,875	88,111	123,083	164,899	214,920	272,467
400	589	1,615	3,323	5,804	9,136	13,594	18,576	25,259	32,845	51,904	76,204	106,464	139,530	186,840	235,877
500	529	1,433	2,980	5,129	8,164	12,039	16,848	22,526	29,430	46,461	68,266	95,785	127,714	164,700	211,048
600	480	1,324	2,721	4,725	7,481	10,970	15,292	20,557	26,865	43,879	62,181	87,145	116,785	151,740	192,753
700	442	1,227	2,505	4,307	6,901	10,187	14,169	19,026	24,840	39,288	57,682	80,924	108,037	140,400	177,071
800	..	1,142	2,354	4,063	6,463	9,526	13,305	17,824	23,220	36,547	53,978	75,740	101,039	131,220	166,617
900	..	1,081	2,203	3,847	6,075	8,996	12,268	16,839	21,870	34,599	50,803	71,248	95,653	124,200	158,122
1,000	..	1,020	2,095	3,678	5,783	8,533	11,836	15,965	20,790	32,853	48,157	67,382	90,541	117,720	148,975
1,760	..	..	1,576	2,767	4,374	6,416	8,985	12,137	17,010	24,688	36,250	50,808	68,284	88,560	112,384
2,640	..	..	1,296	2,261	3,547	5,225	7,257	9,841	12,690	20,217	29,635	41,512	55,549	72,360	91,476
3,520	..	..	1,123	1,957	3,018	4,498	6,307	8,529	11,070	17,526	25,686	35,942	48,114	62,640	79,061
5,280	..	..	..	..	2,527	3,704	5,184	6,889	9,040	14,191	20,905	28,080	39,366	50,760	64,680
7,040	..	..	..	..	..	3,175	4,496	6,014	7,836	12,247	17,992	25,228	34,117	44,280	55,892
8,800	..	..	..	..	..	..	..	5,358	7,020	10,886	16,140	22,464	29,305	39,420	50,811
10,000	..	..	..	..	..	..	..	..	..	10,308	15,081	21,082	28,431	36,720	47,044

TABLES

Of the Discharge of Gas, in Cubic Feet per hour, through Pipes of various Diameters and Lengths at different Pressures.

By THOMAS G. BARLOW. Extended by THOMAS NEWBIGGING.

(The specific gravity of the gas is taken at 0·4, *air being* 1.)

The tables are calculated according to the formula given by Professor Pole in his valuable article* "On the Motion of Fluids in Pipes."

Q = quantity of gas in cubic feet per hour.
l = length of pipe in yards.
d = diameter of pipe in inches.
h = pressure in inches of water.
s = specific gravity of gas, air being 1.

$$Q = 1350\, d^2 \sqrt{\frac{h\,d}{s\,l}}$$

—*i.e.*, multiply the pressure in inches of water by the diameter of the pipe, also in inches. Divide the product by the specific gravity of the gas multiplied by the length of the pipe in yards. Extract the square root of the quotient, which root, multiplied by the constant quantity 1350, and the square of the diameter of the pipe in inches, gives the number of cubic feet discharged in one hour.

EXAMPLE.—It is required to find the number of cubic feet of gas of the specific gravity of ·400, which will be discharged in one hour from a pipe 8 inches in diameter, and 1250 yards in length, under a pressure of 15-10ths, or $1\frac{1}{2}$ inches head of water.

Thus—$(h\,d) = 8 \times 1 \cdot 5 = 12.$

$$\left(\sqrt{\frac{h\,d}{s\,l}} = \frac{12}{\cdot 4 \times 1250}\right) = \cdot 024, \text{ the square root being } = \cdot 1549.$$

$$\left(1350\, d^2 \sqrt{\frac{h\,d}{s\,l}}\right) = 1350 \times 64 \times \cdot 1549 = 13{,}383 \text{ cubic feet} = Q.$$

* See "King's Treatise," Vol. II., p. 374, *et seq.*

Diameter of Pipe, 0·5 *Inch.*

Length in yards.	10.	20.	80.	50.	75.	100.	150.
Quantity delivered with 0·1 in. pressure.	87·7	26·7	21·7	16·8	18·8	11·9	9·7
0·2 "	58·4	87·7	80·6	23·8	19·5	16·8	13·8
0·8 "	65·2	46·8	87·7	29·1	23·8	20·7	16·8
0·4 "	75·2	58·3	43·2	33·7	27·5	23·8	19·5
0·5 "	84·8	59·4	48·6	37·4	30·7	26·7	21·7
0·6 "	92·1	65·1	53·3	41·1	33·7	29·0	23·8
0·8 "	106·7	75·4	61·4	47·5	38·8	33·7	27·4
1·0 "	119·1	84·3	68·8	53·3	43·2	37·7	30·8
1·2 "	130·6	92·1	75·2	58·3	47·5	41·1	33·7
1·5 "	146·1	103·2	84·3	65·1	53·3	45·9	37·8
1·8 "	159·9	113·0	92·1	71·5	58·3	50·6	41·1
2·0 "	168·7	119·1	97·2	75·2	61·4	53·3	43·5
2·5 "	188·6	133·3	108·6	84·3	68·8	59·4	48·6

Diameter of Pipe, 0·75 *Inch.*

Length in yards.	10.	20.	80.	50.	75.	100.	150.
Quantity delivered with 0·1 in. pressure.	104·3	73·8	60·0	46·6	37·9	32·9	26·9
0·2 "	147·5	104·3	84·9	65·8	53·7	46·6	37·9
0·3 "	179·9	126·8	104·3	80·9	65·8	57·0	46·6
0·4 "	207·3	146·5	119·9	93·2	75·9	65·8	53·8
0·5 "	232·3	164·0	133·6	103·2	84·2	73·8	60·0
0·6 "	254·3	179·9	146·5	113·9	92·6	79·7	65·3
0·8 "	293·8	207·3	169·3	131·3	107·0	92·6	75·9
1·0 "	328·8	232·3	189·8	146·5	119·9	103·2	84·2
1·2 "	359·9	254·3	207·3	160·9	131·3	113·9	92·6
1·5 "	402·4	284·0	232·3	179·9	146·5	126·8	103·2
1·8 "	441·1	311·3	254·3	192·2	160·9	138·9	113·9
2·0 "	464·7	328·8	268·0	207·3	169·3	146·5	119·9
2·5 "	519·4	367·5	299·9	232·2	189·8	164·0	133·6

Diameter of Pipe, 1 *Inch.*

Length in yards.	10.	20.	30.	50.	75.	100.	150.
Quantity delivered with 0·1 in. pressure.	214·0	151·0	124·0	95·0	78·0	67·0	55·0
0·2 "	302·0	214·0	175·0	135·0	110·0	95·0	78·0
0·3 "	368·5	260·5	214·0	165·0	135·0	117·0	95·0
0·4 "	426·6	301·0	245·7	190·0	156·0	135·0	110·0
0·5 "	476·5	337·5	274·0	213·3	172·8	151·0	123·0
0·6 "	522·4	368·5	301·0	233·5	190·3	164·7	135·0
0·8 "	603·4	426·6	348·3	270·0	220·0	190·3	155·2
1·0 "	675·0	476·5	388·8	301·0	245·7	213·3	172·8
1·2 "	738·4	522·4	426·6	329·4	270·0	233·5	190·3
1·5 "	826·2	584·5	476·5	368·5	301·0	260·5	213·3
1·8 "	904·5	639·9	522·4	405·0	329·4	286·2	233·5
2·0 "	954·4	675·0	550·8	426·6	348·3	301·0	245·7
2·5 "	1,066·5	754·6	615·6	476·5	388·8	337·5	274·0

Diameter of Pipe, 1·25 *Inches.*

Length in yards.	25.	50.	75.	100.	150.	200.	300.
Quantity delivered with 0·1 in. pressure.	236·0	167·0	137·0	118·0	96·0	84·0	68·0
0·2 „	333·0	236·0	192·0	167·0	137·0	118·0	96·0
0·3 „	407·1	289·0	236·0	205·0	167·0	144·0	118·0
0·4 „	470·3	333·2	272·1	236·0	192·0	167·0	137·0
0·5 „	527·3	371·2	303·7	263·6	215·1	187·0	152·0
0·6 „	575·8	407·1	333·2	286·8	235·8	203·9	166·6
0·8 „	666·5	470·3	383·9	333·2	272·1	235·8	192·3
1·0 „	744·6	527·3	430·3	371·2	303·7	263·6	215·1
1·2 „	816·3	575·8	470·3	407·1	333·2	286·8	235·8
1·5 „	913·3	645·4	527·3	455·6	371·2	322·7	263·6
1·8 „	999·8	706·4	575·8	499·9	407·1	352·2	286·8
2·0 „	1,054·6	744·6	607·5	527·3	430·3	371·2	303·7
2·5 „	1,179·1	833·2	679·2	588·5	480·9	415·5	339·6

Diameter of Pipe, 1·5 *Inches.*

Length in yards.	25.	50.	75.	100.	150.	200.	300.
Quantity delivered with 0·1 in. pressure.	374·0	264·0	215·0	187·0	152·0	132·0	107·0
0·2 „	528·0	374·0	304·0	264·0	215·0	187·0	152·0
0·3 „	643·9	458·0	374·0	322·0	264·0	229·0	187·0
0·4 „	741·1	525·4	428·2	374·0	304·0	264·0	215·0
0·5 „	829·2	586·2	479·9	413·1	339·5	295·0	239·0
0·6 „	911·2	643·9	525·4	455·6	370·5	321·9	261·2
0·8 „	1,050·9	741·1	607·5	525·4	428·2	370·5	303·7
1·0 „	1,175·5	829·2	677·3	586·2	479·9	413·1	339·5
1·2 „	1,287·9	911·2	741·1	643·9	525·4	455·6	370·5
1·5 „	1,439·7	1,017·5	829·2	719·8	586·2	507·2	413·1
1·8 „	1,576·4	1,114·7	911·2	789·1	643·9	555·8	455·6
2·0 „	1,661·5	1,175·5	959·8	829·2	677·3	586·2	479·9
2·5 „	1,858·9	1,315·2	1,072·2	929·4	759·3	656·1	534·6

Diameter of Pipe, 2 *Inches.*

Length in yards.	50.	75.	100.	150.	200.	300.	500.
Quantity delivered with 0·1 in. pressure.	540	441	381	311	270	220	170
0·2 „	763	623	540	441	381	311	241
0·3 „	934	763	665	540	468	381	296
0·4 „	1,080	880	761	623	540	441	341
0·5 „	1,204	983	853	697	604	492	381
0·6 „	1,318	1,080	934	761	659	540	416
0·8 „	1,523	1,242	1,080	880	761	621	481
1·0 „	1,706	1,393	1,204	983	853	697	540
1·2 „	1,868	1,523	1,318	1,080	934	761	589
1·5 „	2,090	1,706	1,474	1,204	1,042	853	659
1·8 „	2,290	1,868	1,620	1,318	1,145	934	724
2·0 „	2,414	1,971	1,706	1,393	1,204	983	761
2·5 „	2,700	2,203	1,906	1,555	1,350	1,102	853

Diameter of Pipe, 2·5 Inches.

Length in yards.	50.	75.	100.	150.	200.	300.	500.
Quantity delivered with 0·1 in. pressure.	943	770	667	545	471	335	298
0·2 „	1,335	1,090	943	770	667	545	421
0·3 „	1,628	1,335	1,172	943	819	667	516
0·4 „	1,882	1,540	1,333	1,090	943	770	596
0·5 „	2,109	1,721	1,485	1,215	1,055	861	667
0·6 „	2,303	1,882	1,628	1,333	1,148	943	731
0·8 „	2,666	2,177	1,882	1,540	1,333	1,088	844
1·0 „	2,978	2,430	2,109	1,721	1,485	1,215	943
1·2 „	3,265	2,666	2,303	1,882	1,628	1,333	1,029
1·5 „	3,653	2,978	2,582	2,109	1,823	1,485	1,148
1·8 „	3,999	3,265	2,827	2,303	2,000	1,628	1,266
2·0 „	4,219	3,443	2,978	2,430	2,109	1,721	1,333
2·5 „	4,717	3,848	3,333	2,717	2,354	1,924	1,485

Diameter of Pipe, 3 Inches.

Length in yards.	100.	150.	250.	500.	750.	1000.	1250.
Quantity delivered with 0·1 in pressure.	1,054	859	666	471	384	333	298
0·2 „	1,440	1,214	942	666	543	471	375
0·3 „	1,823	1,487	1,153	815	666	576	529
0·4 „	2,102	1,713	1,332	942	768	666	596
0·5 „	2,345	1,920	1,482	1,054	859	744	666
0·6 „	2,576	2,102	1,628	1,152	942	815	739
0·8 „	2,965	2,430	1,882	1,324	1,081	942	845
1·0 „	3,317	2,709	2,102	1,482	1,215	1,052	942
1·2 „	3,645	2,965	2,296	1,628	1,324	1,152	1,030
1·5 „	4,070	3,317	2,576	1,823	1,482	1,288	1,152
1·8 „	4,459	3,645	2,819	1,993	1,628	1,409	1,262
2·0 „	4,702	3,839	2,965	2,102	1,713	1,482	1,324
2·5 „	5,261	4,289	3,317	2,345	1,920	1,652	1,482

Diameter of Pipe, 4 Inches.

Length in yards.	100.	250.	500.	750.	1000.	1250.	1500.
Quantity delivered with 0·1 in pressure.	2,160	1,366	966	788	683	611	557
0·2 „	3,054	1,932	1,366	1,114	966	864	788
0·3 „	3,737	2,366	1,673	1,366	1,183	1,058	966
0·4 „	4,320	2,722	1,932	1,576	1,366	1,222	1,114
0·5 „	4,817	3,046	2,160	1,761	1,526	1,366	1,245
0·6 „	5,270	3,346	2,354	1,932	1,672	1,496	1,366
0·8 „	6,091	3,845	2,722	2,225	1,932	1,728	1,576
1·0 „	6,826	4,320	3,046	2,484	2,160	1,932	1,761
1·2 „	7,474	4,730	3,346	2,722	2,354	2,115	1,922
1·5 „	8,359	5,270	3,737	3,046	2,635	2,354	2,160
1·8 „	9,158	5,789	4,082	3,346	2,894	2,592	2,354
2·0 „	9,655	6,091	4,320	3,521	3,046	2,722	2,484
2·5 „	10,800	6,826	4,817	3,931	3,413	3,046	2,786

Diameter of Pipe, 5 Inches.

Length in yards.	100.	250.	500.	750.	1000.	1250.	1500.
Quantity delivered with 0·1 in. pressure.	3,540	2,245	1,587	1,296	1,122	1,000	910
0·2 "	5,005	3,174	2,245	1,832	1,587	1,414	1,296
0·3 "	6,514	3,888	2,748	2,245	1,943	1,732	1,575
0·4 "	7,526	4,759	3,174	2,592	2,245	2,000	1,820
0·5 "	8,438	5,333	3,778	2,888	2,508	2,236	1,934
0·6 "	9,214	5,839	4,118	3,174	2,748	2,449	2,245
0·8 "	10,665	6,750	4,759	3,881	3,174	2,828	2,596
1·0 "	11,914	7,526	5,333	4,354	3,778	3,174	2,877
1·2 "	13,061	8,235	5,839	4,759	4,118	3,679	3,375
1·5 "	14,614	9,214	6,514	5,333	4,590	4,118	3,540
1·8 "	15,998	10,125	7,156	5,839	5,063	4,523	4,118
2·0 "	16,875	10,665	7,526	6,143	5,333	4,759	4,354
2·5 "	18,866	11,914	8,438	6,885	5,940	5,333	4,860

Diameter of Pipe, 6 Inches.

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0·1 in. pressure.	3,770	2,660	2,170	1,880	1,680	1,530	1,420
0·2 "	5,320	3,770	3,130	2,660	2,370	2,170	2,010
0·3 "	6,530	4,620	3,770	3,270	2,920	2,660	2,460
0·4 "	7,540	5,320	4,340	3,770	3,360	3,060	2,840
0·5 "	8,408	5,970	4,860	4,210	3,770	3,430	3,180
0·6 "	9,185	6,512	5,320	4,620	4,130	3,770	3,460
0·8 "	10,643	7,528	6,124	5,320	4,740	4,340	4,020
1·0 "	11,858	8,408	6,853	5,929	5,320	4,860	4,500
1·2 "	13,025	9,185	7,528	6,512	5,832	5,297	4,929
1·5 "	14,580	10,303	8,408	7,290	6,512	5,970	5,500
1·8 "	15,941	11,275	9,185	7,970	7,139	6,512	6,026
2·0 "	16,816	11,858	9,720	8,408	7,528	6,853	6,360
2·5 "	18,808	13,268	10,838	9,380	8,408	7,679	7,096

Diameter of Pipe, 7 Inches.

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0·1 in. pressure.	5,560	3,920	3,200	2,780	2,470	2,270	2,100
0·2 "	7,840	5,560	4,510	3,920	3,500	3,200	2,960
0·3 "	9,600	6,800	5,560	4,800	4,300	3,920	3,640
0·4 "	11,120	7,840	6,400	5,560	4,940	4,540	4,200
0·5 "	12,370	8,750	7,180	6,200	5,560	5,060	4,680
0·6 "	13,554	9,585	7,840	6,800	6,080	5,560	5,130
0·8 "	15,611	11,047	8,996	7,840	7,020	6,400	5,930
1·0 "	17,463	12,370	10,054	8,732	7,840	7,180	6,610
1·2 "	19,170	13,554	11,047	9,585	8,533	7,805	7,210
1·5 "	21,433	15,148	12,370	10,716	9,585	8,750	8,120
1·8 "	23,477	16,597	13,554	11,709	10,452	9,855	8,864
2·0 "	24,740	17,463	14,288	12,370	11,047	10,054	9,860
2·5 "	27,651	19,567	15,942	13,825	12,370	11,292	10,452

Diameter of Pipe, 8 *Inches.*

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0·1 in. pressure.	7,760	5,470	4,470	3,880	3,460	3,160	2,920
0·2 ,,	10,940	7,760	6,310	5,470	4,880	4,470	4,130
0·3 ,,	13,400	9,450	7,760	6,700	5,980	5,470	5,050
0·4 ,,	15,520	10,940	8,940	7,760	6,920	6,320	5,840
0·5 ,,	17,280	12,200	9,900	8,640	7,760	7,020	6,520
0·6 ,,	18,922	13,383	10,940	9,450	8,480	7,760	7,150
0·8 ,,	21,851	15,379	12,614	10,940	9,780	8,940	8,260
1·0 ,,	24,365	17,280	14,083	12,182	10,940	9,900	9,237
1·2 ,,	26,767	18,922	15,379	13,383	11,923	10,886	10,109
1·5 ,,	29,894	21,082	17,280	14,947	13,383	12,200	11,300
1·8 ,,	32,746	23,155	18,922	16,330	14,602	13,383	12,355
2·0 ,,	34,560	24,365	19,872	17,280	15,379	14,083	13,040
2·5 ,,	38,621	27,302	22,291	19,267	17,280	15,725	14,602

Diameter of Pipe, 9 *Inches.*

Length in yards.	250.	500.	750.	1000.	1250.	1500.	1750.
Quantity delivered with 0·1 in. pressure.	10,400	7,380	6,350	5,200	4,650	4,250	3,950
0·2 ,,	14,760	10,400	8,500	7,380	6,480	6,000	5,620
0·3 ,,	18,000	12,780	10,400	9,000	8,300	7,380	6,800
0·4 ,,	20,800	14,760	12,700	10,400	9,300	8,500	7,900
0·5 ,,	23,182	16,500	13,420	11,900	10,400	9,680	8,800
0·6 ,,	25,369	17,933	14,760	12,780	11,400	10,400	9,650
0·8 ,,	29,306	20,667	16,938	14,760	13,100	12,000	11,050
1·0 ,,	32,805	23,182	18,918	16,403	14,760	13,420	12,380
1·2 ,,	35,867	25,369	20,667	17,933	16,064	14,653	13,559
1·5 ,,	40,181	28,409	23,182	20,011	17,933	16,500	15,200
1·8 ,,	43,959	31,055	25,369	21,979	19,683	17,933	16,621
2·0 ,,	46,364	32,805	26,681	23,182	20,667	18,918	17,600
2·5 ,,	51,832	36,632	29,853	25,916	23,182	21,105	19,574

Diameter of Pipe, 10 *Inches.*

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0·1 in. pressure.	9,560	7,800	6,750	6,050	5,520	5,100	4,780
0·2 ,,	13,500	11,040	9,560	8,520	7,800	7,300	6,750
0·3 ,,	16,500	13,500	11,700	10,520	9,560	8,850	8,259
0·4 ,,	19,120	15,600	13,500	12,100	11,040	10,200	9,560
0·5 ,,	21,300	17,400	15,050	13,500	12,380	11,400	10,650
0·6 ,,	23,355	19,120	16,500	14,800	13,500	12,500	11,650
0·8 ,,	27,000	22,005	19,120	17,050	15,600	14,400	13,500
1·0 ,,	30,105	24,570	21,330	19,120	17,400	16,150	15,050
1·2 ,,	32,940	27,000	23,355	20,911	19,035	17,550	16,578
1·5 ,,	36,855	30,105	26,055	23,355	21,300	19,600	18,500
1·8 ,,	40,500	32,940	28,620	25,515	23,355	21,600	20,250
2·0 ,,	42,660	34,830	30,105	27,000	24,570	22,800	21,300
2·5 ,,	47,655	38,880	33,750	30,105	27,540	25,501	23,760

Diameter of Pipe, 12 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered with 0·1 in. pressure.	15,100	12,800	10,700	9,550	8,700	8,050	7,550
0·2 "	21,400	17,400	15,100	13,450	12,300	11,350	10,700
0·3 "	26,100	21,400	19,500	16,500	15,100	13,880	13,050
0·4 "	30,200	24,600	21,400	19,100	17,400	16,100	15,100
0·5 "	33,600	27,500	23,800	21,400	19,440	18,050	16,800
0·6 "	36,741	30,200	26,100	23,300	21,400	19,800	19,500
0·8 "	42,573	34,603	30,200	26,900	24,600	22,700	21,400
1·0 "	47,433	38,880	33,631	30,200	27,500	25,450	23,800
1·2 "	52,099	42,573	36,741	32,853	30,112	27,799	26,049
1·5 "	58,320	47,433	41,212	36,741	33,600	31,250	29,250
1·8 "	63,763	52,099	45,100	40,396	36,741	34,020	31,881
2·0 "	67,262	54,820	47,433	42,573	38,880	36,100	33,600
2·5 "	75,232	61,430	53,071	47,433	43,351	40,240	37,519

Diameter of Pipe, 14 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered. with 0·1 in. pressure.	22,100	18,100	15,600	13,950	12,750	11,800	11,050
0·2 "	31,200	25,500	22,100	19,800	18,100	16,700	15,600
0·3 "	38,400	31,200	27,100	24.250	22,100	20,500	19.200
0·4 "	44,200	36,200	31,200	27,900	25,500	23,600	22.100
0·5 "	49,400	40,400	35,000	31,200	28,500	26,460	24,700
0·6 "	54,216	44,200	38,400	34,300	31,200	28,900	27,100
0·8 "	62,445	51,067	44,200	39,600	36,200	33,400	31,200
1·0 "	69,854	57,153	49,480	44,200	40,400	37,300	35,000
1·2 "	76,681	62,445	54,216	48,421	44,188	40,986	38.340
1·5 "	85,730	69,854	60,593	54.216	49,400	45,700	42,600
1·8 "	93,906	76,681	66,414	59,270	54,216	50,009	46,834
2·0 "	98,960	80,703	69,854	62,445	57,153	52,920	49,400
2·5 "	110,602	90,228	78,268	69,854	63,768	59,005	55,301

Diameter of Pipe, 15 Inches.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered. with 0·1 in. pressure.	26,300	21,400	18,600	16,600	15,200	14,000	13,150
0·2 "	37,200	30,400	26,300	23,500	21,400	19,900	18.600
0·3 "	45,500	37,200	32,250	28,750	26,300	24,300	22,750
0·4 "	52,600	42,800	37,200	33,200	30,400	28,000	26.300
0·5 "	58,700	48,000	41,600	37,200	34,000	31,400	29,350
0·6 "	64,395	52,600	45,500	40,700	37,200	34,450	32.250
0·8 "	74.115	60,750	52,600	47,000	42,800	39,800	37;200
1·0 "	82,923	67,736	58,623	52,600	48,000	44,400	41,600
1·2 "	91,125	74,115	64,395	57,408	52,548	48,600	45,562
1·5 "	101,756	82,923	71,983	64,395	58,700	54,300	50,800
1·8 "	111,476	91,125	78,914	70,470	64,395	59,535	55.586
2·0 "	117,551	95,985	82,923	74,115	67,736	62,800	58,700
2·5 "	131,523	107,223	92,947	82,923	75,937	70,166	65,610

Diameter of Pipe, 16 *Inches*.

Length in yards.	500.	750.	1000.	1250.	1500.	1750.	2000.
Quantity delivered. with 0·1 in. pressure.	31,000	25,250	21,850	19,550	17,850	16,550	15,500
0·2 "	43,700	35,700	31,000	27,700	25,250	23,400	21,850
0·3 "	53,600	43,700	38,100	34,000	31,000	28,700	26,800
0·4 "	62,000	50,500	43,700	39,100	35,700	33,100	31,000
0·5 "	69,120	56,600	49,000	43,700	39,900	37,150	34,560
0·6 "	75,686	62,000	53,600	47,900	43,700	38,100	40,700
0·8 "	87,402	71,193	62,000	55,400	50,500	46,800	43,700
1·0 "	97,459	79,488	69,120	62,000	56,600	52,400	49,000
1·2 "	107,066	87,402	75,686	67,703	61,516	57,024	53,533
1·5 "	119,577	97,459	84,326	75,686	69,120	63,900	60,100
1·8 "	130,982	107,066	92,620	82,944	75,686	70,087	65,318
2·0 "	138,240	112,665	97,459	87,402	79,488	74,300	69,120
2·5 "	154,483	126,144	109,209	97,459	89,164	82,598	77,068

Diameter of Pipe, 18 *Inches*.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	41,400	33,800	29,400	23,900	20,700	18,400	16,900
0·2 "	58,800	47,800	41,400	33,800	29,400	26,200	23,900
0·3 "	71,800	58,800	50,800	41,400	35,900	32,100	29,400
0·4 "	82,800	67,600	58,800	47,800	41,400	36,800	33,800
0·5 "	92,600	75,700	65,600	53,500	46,300	41,400	37,850
0·6 "	101,476	82,800	71,800	58,800	50,800	45,400	41,400
0·8 "	117,223	95,790	82,800	67,600	58,800	52,300	47,800
1·0 "	131,220	106,725	92,728	75,700	65,600	58,800	53,500
1·2 "	143,467	117,223	101,476	82,668	71,733	64,254	58,611
1·5 "	161,400	131,220	113,636	92,728	80,000	71,800	65,600
1·8 "	175,834	143,467	124,221	101,476	87,917	78,732	71,733
2·0 "	185,457	151,340	131,220	106,725	92,728	82,800	75,700
2·5 "	207,327	169,273	146,529	119,410	103,663	92,728	84,500

Diameter of Pipe, 20 *Inches*.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	54,000	44,000	38,250	31,200	27,000	24,200	22,000
0·2 "	76,500	62,400	54,000	44,000	38,250	34,200	31,200
0·3 "	93,500	76,500	66,100	54,000	46,750	41,800	38,250
0·4 "	108,000	88,000	76,500	62,400	54,000	48,400	44,000
0·5 "	120,500	98,800	85,300	69,800	62,250	54,000	49,400
0·6 "	131,760	108,000	93,500	76,500	66,100	59,100	54,000
0·8 "	152,280	124,200	108,000	88,000	76,500	68,400	62,400
1·0 "	170,640	139,320	120,420	98,800	85,300	76,500	69,800
1·2 "	186,840	152,280	131,760	108,000	93,420	83,646	76,140
1·5 "	208,980	170,640	147,420	120,420	102,300	93,500	85,300
1·8 "	228,960	186,840	162,000	131,760	114,480	102,060	93,420
2·0 "	241,380	197,100	170,640	139,320	120,420	108,000	98,800
2·5 "	270,000	220,320	190,620	155,520	135,000	120,420	110,200

Diameter of Pipe, 22 Inches.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	68,600	56,000	48,400	39,600	34,300	30,700	28,000
0·2 ,,	96,800	79,200	68,600	56,000	48,000	43,400	39,600
0·3 ,,	118,800	96,800	84,000	68,600	59,400	53,300	48,400
0·4 ,,	137,200	112,000	96,800	79,200	68,600	61,400	56,000
0·5 ,,	153,500	122,500	108,200	88,600	76,800	68,400	61,200
0·6 ,,	168,577	137,200	118,800	96,800	84,000	75,000	68,600
0·8 ,,	193,406	158,122	137,200	112,000	96,800	86,500	79,200
1·0 ,,	216,275	176,418	152,895	122,500	108,200	96,800	88,600
1·2 ,,	237,184	193,406	168,577	136,560	118,265	105,850	96,703
1·5 ,,	265,280	216,275	187,525	152,895	132,000	118,800	108,200
1·8 ,,	290,697	237,184	203,860	168,577	145,054	130,026	118,265
2·0 ,,	306,444	249,598	216,275	176,418	152,895	137,200	122,500
2·5 ,,	342,381	279,655	242,280	197,326	171,190	152,895	140,000

Diameter of Pipe, 24 Inches.

Length in yards.	500.	750.	1000.	1500.	2000.	2500.	3000.
Quantity delivered with 0·1 in. pressure.	84,000	68,600	59,500	48,500	42,000	37,500	34,300
0·2 ,,	119,000	97,000	84,000	68,600	59,500	53,400	48,500
0·3 ,,	145,500	119,000	103,000	84,000	72,700	65,200	59,500
0·4 ,,	168,000	137,200	119,000	97,000	84,000	75,000	68,600
0·5 ,,	187,500	155,000	135,600	108,600	93,800	84,000	77,500
0·6 ,,	208,396	168,000	145,000	119,000	103,000	92,000	84,000
0·8 ,,	240,900	196,655	168,000	137,200	119,000	106,000	97,000
1·0 ,,	269,049	219,283	189,734	155,000	135,600	119,000	108,600
1·2 ,,	294,710	240,900	208,396	170,294	146,966	131,414	120,450
1·5 ,,	329,702	269,049	233,280	189,734	163,000	145,500	135,600
1·8 ,,	360,806	294,710	255,052	208,396	180,403	161,585	146,966
2·0 ,,	380,946	311,040	269,049	219,283	189,734	168,000	155,000
2·5 ,,	425,347	347,587	300,931	245,721	212,284	189,734	172,000

Diameter of Pipe, 26 Inches.

Length in yards.	750.	1000.	1500.	2000.	2500.	3000.	4000.
Quantity delivered with 0·1 in. pressure.	85,000	73,500	60,000	52,000	46,500	42,500	36,750
0·2 ,,	120,000	104,000	85,000	73,500	65,800	60,000	52,000
0·3 ,,	147,000	127,000	104,0 0	90,000	80,600	73,500	63,500
0·4 ,,	170,000	147,000	120,000	104,000	93,000	85,000	73,500
0·5 ,,	189,000	165,000	134,000	116,000	104,000	94,500	82,500
0·6 ,,	208,000	180,000	147,000	127,000	114,000	104,000	90,000
0·8 ,,	240,013	208,000	170,000	147,000	132,000	120,000	104,000
1·0 ,,	268,304	232,621	189,000	165,000	147,000	134,000	116,000
1·2 ,,	293,857	254,615	208,072	179,782	160,617	146,928	126,851
1·5 ,,	328,536	284,731	232,621	201,000	180,000	165,000	142,000
1·8 ,,	360,385	312,109	254,615	220,666	197,121	179,782	156,054
2·0 ,,	379,641	328,536	268,304	232,621	208,000	189,000	165,000
2·5 ,,	424,359	367,777	300,245	260,091	232,621	213,000	184,000
3·0 ,,	465,334	402,456	328,536	284,731	254,615	232,621	201,000

Diameter of Pipe, 28 Inches.

Length in yards.	1000.	1500.	2000.	2500.	3000.	4000.	5000.
Quantity delivered with 0·5 in. pressure.	198,000	161,000	140,000	125,000	114,500	99,000	88,600
0·6 ,,	216,866	176,752	153,362	136,533	124,891	107,956	96,314
0·8 ,,	249,732	204,271	176,752	157,701	143,942	124,891	111,978
1·0 ,,	280,000	229,000	198,000	177,000	161,000	140,000	125,000
1·2 ,,	306,724	249,732	216,866	193,687	176,752	153,362	136,533
1·5 ,,	342,921	280,000	241,000	216,000	198,000	171,000	153,500
1·8 ,,	375,626	306,724	265,658	237,081	216,866	187,336	167,227
2·0 ,,	395,841	322,812	280,000	250,000	229,000	198,000	177,200
2·5 ,,	442,411	360,914	313,074	280,000	255,000	222,000	198,000
3·0 ,,	484,747	395,841	342,921	306,724	280,000	241,000	216,000

Diameter of Pipe, 30 Inches.

Length in yards.	1000.	2000.	3000.	4000.	5000.	7500.	10000.
Quantity delivered with 0·5 in. pressure.	234,000	166,000	135,000	117,000	105,000	86,000	74,500
0·6 ,,	257,580	182,250	148,230	128,790	115,182	94,041	81,405
0·8 ,,	296,460	210,195	171,315	148,230	132,435	108,135	94,041
1·0 ,,	332,000	234,000	192,000	166,000	149,000	121,500	105,000
1·2 ,,	364,500	257,580	210,195	182,250	162,810	132,435	115,182
1·5 ,,	407,025	287,000	234,000	203,000	182,000	149,000	128,500
1·8 ,,	445,905	315,657	257,580	222,345	199,260	162,810	140,940
2·0 ,,	470,205	331,695	270,000	234,000	210,000	172,000	149,000
2·5 ,,	526,095	371,790	303,750	263,000	234,000	192,000	166,000
3·0 ,,	575,910	407,025	331,695	287,955	257,000	210,000	182,000
4·0 ,,	664,605	470,205	383,940	331,695	298,000	243.000	210,000

Diameter of Pipe, 36 Inches.

Length in yards.	1000.	2000.	3000.	4000.	5000.	7500.	10000.
Quantity delivered with 0·5 in. pressure.	370,915	262,440	218,451	185,457	165,862	135,419	117,223
0·6 ,,	405,907	286,934	234,446	202,953	181,783	148,366	127,720
0·8 ,,	468,892	330,674	271,013	234,446	209,952	171,285	148,366
1·0 ,,	530,000	370,000	303,000	265,000	234,000	192,000	166,000
1·2 ,,	573,868	405,907	330,674	286,934	257,016	209,952	181,783
1·5 ,,	642,103	456,000	372,000	322,000	288,000	234,900	204.000
1·8 ,,	703,339	496,886	405,907	351,669	314,928	257,016	222,199
2·0 ,,	741,830	524,880	428,000	372,000	332,000	271,000	234 000
2·5 ,,	829,310	586,116	477,640	416,000	372,000	303,000	265.000
3·0 ,,	908,042	642,103	524,880	454,546	407,000	332,000	288,000
4·0 ,,	1,049,760	742,180	605,361	524,880	468,892	384,000	332,000

The foregoing tables are calculated upon the basis of the specific gravity of the gas being ·400. The quantity of gas of any other specific gravity discharged may be ascertained by multiplying the quantity indicated in the table by ·6325 (the square root of ·400), and dividing by the square root of the specific gravity of the other gas.

Example.—If a 12-inch pipe, 1000 yards long, discharges 23,800 cubic feet of gas per hour, specific gravity ·400 at ·5 in. pressure, how much gas will the same pipe discharge, at the same pressure, when the specific gravity is ·560?

$$\frac{23{,}800 \times \cdot 6325}{\cdot 7483} = 20{,}116 \text{ cubic feet.}$$

The quantity of gas discharged at any other pressure may be ascertained by multiplying the quantity indicated in the table by the square root of the new pressure, and dividing by the square root of the original pressure.

Example.—If a quantity of gas equal to 23,355 cubic feet is discharged in one hour at a pressure of 1·2 inches, what quantity will be discharged through the same pipe at 2·2 inches pressure?

$$\frac{23{,}355 \times 1 \cdot 4832}{1 \cdot 0954} = 31{,}623 \text{ cubic feet.}$$

To facilitate these calculations, tables are annexed of the square roots of specific gravities from ·350 to ·700, rising ·005 at a time; and of the square roots of pressures from 1-10th of an inch to 4 inches, rising 1-10th at a time.

TABLE.

Square Root of the Specific Gravity of Gas from ·350 to ·700.

Specific Gravity.	Square Root.	Specific Gravity.	Square Root.	Specific Gravity.	Square Root.	Specific Gravity.	Square Root.	Specific Gravity.	Square Root.
·350	·5916	·425	·6519	·495	·7035	·565	·7517	·635	·7969
·355	·5958	·430	·6557	·500	·7071	·570	·7549	·640	·8000
·360	·6000	·435	·6595	·505	·7106	·575	·7583	·645	·8031
·365	·6041	·440	·6633	·510	·7141	·580	·7616	·650	·8062
·370	·6083	·445	·6671	·515	·7176	·585	·7648	·655	·8093
·375	·6124	·450	·6708	·520	·7212	·590	·7681	·660	·8124
·380	·6164	·455	·6745	·525	·7246	·595	·7713	·665	·8155
·385	·6205	·460	·6782	·530	·7280	·600	·7746	·670	·8185
·390	·6245	·465	·6819	·535	·7314	·605	·7778	·675	·8216
·395	·6285	·470	·6856	·540	·7348	·610	·7810	·680	·8246
·400	·6325	·475	·6892	·545	·7382	·615	·7842	·685	·8276
·405	·6364	·480	·6928	·550	·7416	·620	·7874	·690	·8306
·410	·6403	·485	·6964	·555	·7449	·625	·7905	·695	·8337
·415	·6442	·490	·7000	·560	·7483	·630	·7937	·700	·8367
·420	·6481								

TABLE.

Square Root of Pressures, rising by Tenths of an Inch, from One-Tenth to Four Inches.

Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.	Inches and Tenths.	Square Root.
1-10th.	·3162	1·5-10ths.	1·2251	2·8-10ths.	1·6733
2-10ths.	·4472	1·6 ,,	1·2649	2·9 ,,	1·7029
3 ,,	·5477	1·7 ,,	1·3038	3 inches.	1·7320
4 ,,	·6324	1·8 ,,	1·3416	3·1-10th.	1·7606
5 ,,	·7071	1·9 ,,	1·3784	3·2-10ths.	1·7888
6 ,,	·7745	2 inches.	1·4142	3·3 ,,	1·8165
7 ,,	·8366	2·1-10th.	1·4491	3·4 ,,	1·8439
8 ,,	·8944	2·2-10ths.	1·4832	3·5 ,,	1·8708
9 ,,	·9487	2·3 ,,	1·5165	3·6 ,,	1·8973
1 inch.	1·0000	2·4 ,,	1·5491	3·7 ,,	1·9235
1·1-10th.	1·0488	2·5 ,,	1·5811	3·8 ,,	1·9493
1·2-10ths.	1·0954	2·6 ,,	1·6123	3·9 ,,	1·9748
1·3 ,,	1·1401	2·7 ,,	1·6431	4 inches.	2·0000
1·4 ,,	1·1832				

Should it be required to find the pressure in inches of water to discharge a certain quantity of gas of given specific gravity in an hour, through a pipe the dimensions of which are known, the formula is—

$$h = \frac{Q^2\, s\, l}{(1350)^2\, d^5}$$

i.e., multiply the square of the number of cubic feet of gas to be discharged in one hour by the specific gravity of the gas, and by the length of the pipe in yards; divide the product by the square of the constant number 1350, multiplied by the diameter in inches raised to the fifth power, and the quotient is the pressure.

EXAMPLE.—It is required to find the pressure in inches of water to discharge in an hour 12,000 cubic feet of gas, specific gravity ·5, through a pipe 8 inches in diameter and 1900 yards long. Then,—

$$\frac{Q^2 \times s \times l}{1350^2 \times d^5} = \frac{144{,}000{,}000 \times \cdot 5 \times 1900}{1{,}822{,}500 \times 32{,}768} \times \frac{136{,}800{,}000{,}000}{59{,}719{,}680{,}000} = \begin{cases} 2\cdot 3 \text{ ins.} \\ \text{nearly.} \end{cases}$$

If the diameter of a pipe is required which will discharge a given quantity of gas under a given pressure, we have the formula—

$$d = \sqrt[5]{\frac{Q^2\, s\, l}{(1350)^2\, h}}$$

This can easily be calculated by a table of logarithms—thus,—

$\log. d = \frac{1}{5} (2 \log. Q. + \log. s. + \log. l. - 2 \log. 1350 + \log. h.)$

EXAMPLE.—It is required to find the diameter of a pipe 1240 yards long, to discharge 48,000 cubic feet of gas, of the specific gravity ·4, in one hour, with a pressure of 2 inches. Then,—

$$\begin{array}{lclcr}
2 \log. Q = 2 \log. 48{,}000 & \ldots & & = & 9\cdot3624824 \\
\log. s = \log. \cdot4 & \ldots & & = & -1\cdot6020600 \\
\log. l = \log. 1240 & \ldots & & = & 3\cdot0934217 \\
\hline
 & & & & 12\cdot0579641 \\
2 \log. 1350 = 6\cdot2606676 & & & & \\
\log. h = \log. 2 = 0\cdot3010300 & & & = & 6\cdot5616976 \\
\hline
 & & & & 5\;)\;5\cdot4962665 \\
\hline
\log. d & \ldots & & = & 1\cdot0992533
\end{array}$$

Therefore $d = 13$ inches, nearly.

The following axioms are worth remembering:—

1. The discharge of gas will be doubled when the length of the pipe is only one-fourth of any of the lengths given in the tables.
2. The discharge of gas will be only one-half when the length of the pipe is four times greater than the lengths given in the tables.
3. The discharge of gas will be doubled by the application of four times the pressure.

Handy Rule for finding (approximately) the Content of a Pipe in Gallons and Cubic Feet.

RULE.—Multiply the square of the diameter of the pipe in inches by the length in yards, and divide by 10 for gallons, and by 60 for cubic feet.

EXAMPLE.—A pipe is 6 in. diameter and 400 yards long, what is the content? then—

$$6^2 \times 400 \begin{array}{l} \div 10 = 1440 \text{ gallons.} \\ \div 60 = \;\;240 \text{ cubic feet.} \end{array}$$

SERVICE-PIPES AND FITTINGS.

In the term service-pipes are included all pipes branching out of the mains to consumers' meters, and for the supply of public and private lamps.

Leakage or unaccounted-for gas is due more to defects in service-pipes than to all the other causes combined. The leaks are chiefly caused in the pipe by corrosion, or at its junction with the main. Such being the case, it is clear that the utmost care should be devoted to the habilitation and maintenance of this portion of the distributory plant.

Service-pipes are of cast-iron, wrought-iron, and lead. The use of cast-iron pipes for this purpose is, as a general rule, confined to the supply of gas to large establishments, where the diameter of the pipe required exceeds 2 inches. The smaller sizes are too fragile to bear the overhead traffic, and the number of joints is objectionable. Such services as are of less bore than 3 inches are usually of wrought-iron, or lead.

Wrought-iron pipes or tubes are chiefly employed for services. They can be obtained of any convenient length, and are easily and expeditiously fixed.

Wrought-iron tubes and fittings, such as tees, bends, elbows, ferrules, sockets, &c., should be perfectly cylindrical, with no ribs or flat places, and internally as smooth as possible. The welding should be scarcely discernible from the other parts, and the screw should be equally deep throughout the thread.

In laying wrought-iron pipes, the coupling or socket at the end, and which is supplied along with the pipe, should always be removed, the thread painted with red or white lead paint, and then replaced.

Lead pipes have their advantages, though they require more care in laying; and to prevent their sagging in the ground, wood lags have to be placed underneath them throughout their length.

On the other hand, they can be laid with fewer joints; the only jointing places being the connections with the main and the meter, unless the premises to be supplied is beyond the ordinary distance from the main. When taken up, also, to be renewed, the old metal is of more value than old iron.

All service-pipes, whether of wrought-iron or lead, when laid in the ground, should be protected from the oxidizing influences of the soil, moisture, and air, by being encased in a ⊔-shaped or V-shaped channel of wood or other material, filled, after the pipe has been laid therein, with a mixture of hot pitch and tar. This prolongs their life

indefinitely, and prevents leakage, and consequently is well worth the trifling extra cost and trouble entailed.

It is not possible always to see whether a wrought-iron service-pipe is worn out or not, unless it is taken up out of the ground. The under part of the pipe will often be found completely oxidized, when the upper surface is sound and good. The rust forms a shell which crumbles on being disturbed, but when untouched is sufficient to prevent the immediate escape of gas.

The tinning or galvanizing of the surface of wrought-iron pipes adds greatly to their durability in sandy soil impregnated with saline matter.

Various processes have been devised for covering iron with a thin layer of oxide to protect it from corrosion either in the soil or when exposed to the atmosphere, and they are peculiarly valuable when applied to wrought-iron tubes and fittings.

Mains should be drilled, not cut with a chisel, for the insertion of service-pipes. The full sectional thickness of the metal is thus preserved, and the hole is a true circle in form.

Several makers supply drilling apparatus which secures immunity from leakage in attaching the service-pipe to the main; and it is easily applied and used.

All service-pipes should, if possible, be laid with a slight fall to the main to admit of the condensed moisture draining away thereto. When the pipe is of great length, and a continuous inclination to the main is impracticable, a small drip-well, commonly called a bottle-syphon (Fig. 30 on page 249) should be attached at the lowest point.

The service-cleansers of D. Hulett and Co. (Fig. 120), of W. & B. Cowan (Fig. 121), and of Hutchinson Bros. (Fig. 122), are exceedingly useful for removing water and other obstructions from service-pipes.

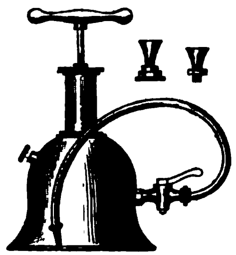


Fig. 120.

All abrupt angles, such as square elbows, whether in mains, services, or internal fittings, owing to the resistance they offer to the regular and even flow of the gas, act as condensers, and diminish the available pressure. Their use should, therefore, be discarded wherever practicable; bends or round elbows being much more preferable. For the same reason the internal surface of pipes should be as smooth as possible. No pipe should be put in use without careful examination and the removal of all existing roughnesses.

2-inch cast-iron pipes as mains,
½-inch wrought-iron pipes as services, and
¼-inch lead or composition pipes for internal supply, should be utterly abandoned.

The first are a grievous source of direct leakage, owing to breakages at their junction with the service-pipes ; the whole three, if used to

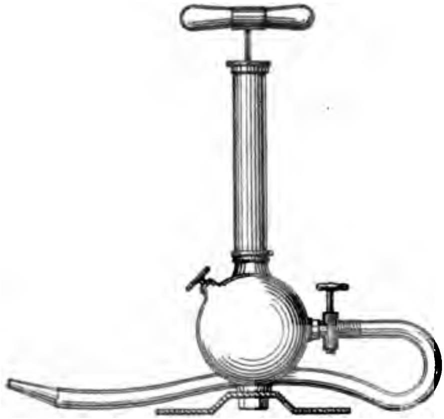


Fig. 121.

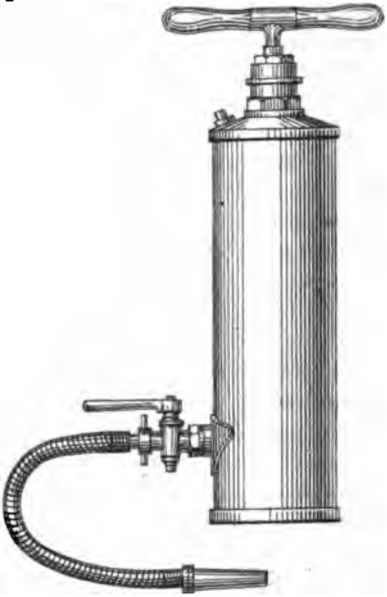


Fig. 122.

any great extent, entail high initial pressure, which is synonymous with a heavy leakage account.

If the distance from the main to the meter does not exceed 30 yards, the following sizes of service-pipes will supply the number of lights named :—

	Wrought-iron Tube.
1 to 10 lights (consuming say 4 c. ft. per hour each) .	¾ inch.
11 ,, 30 ,, ,, ,, ,, .	1 ,,
31 ,, 60 ,, ,, ,, ,, .	1¼ ,,
61 ,, 120 ,, ,, ,, ,, .	1½ ,,
121 ,, 200 ,, ,, ,, ,, .	2 ,,

The above sizes allow for partial contraction of the area of the pipe by corrosion or deposition.

TABLE.

Weight per Foot of Wrought-Iron Tubing

For Gas, Water, and Steam.

Gas.			Water.			Steam.		
Internal Diameter.	Weight per Foot.		Internal Diameter.	Weight per Foot.		Internal Diameter.	Weight per Foot.	
Inches.	Lbs.	Ozs.	Inches.	Lbs.	Ozs.	Inches.	Lbs.	Ozs.
½	0	14½	½	0	15	½	0	15½
¾	1	5½	¾	1	7½	¾	1	8
1	1	15	1	2	1	1	2	8¾
1¼	2	10	1¼	2	14	1¼	3	4
1½	3	2½	1½	3	9	1½	4	0
2	4	6½	2	4	14	2	5	8
2½	5	10½	2½	6	4	2½	7	0

TABLE.

Weight of Wrought-Iron Gas Tubes and Fittings.

Internal Diameter	Tubes.							Fittings.					
Inches.	Weight per 100 feet.			Weight per 1000 feet.				Weight of 10 Elbows.		Weight of 10 Tees.		Weight of 10 Crosses.	
	Cwts.	Qrs.	Lbs.	Tons.	Cwts.	Qrs.	Lbs.	Lbs.	Ozs.	Lbs.	Ozs.	Lbs.	Ozs.
⅛	0	1	0	0	2	2	0	1	1	1	0	1	8
¼	0	1	14	0	3	3	0	1	7	1	8	1	14
⅜	0	2	6	0	5	2	4	1	13	2	4	2	3
½	0	3	6½	0	8	0	9½	2	15	3	0	3	4
¾	1	0	22½	0	12	0	1	4	6	5	4	5	11
1	1	2	26	0	17	1	8	6	4	7	10	9	2
1¼	2	1	11	1	3	1	26	10	10	12	15	14	11
1½	2	3	7	1	8	0	14	15	8	16	7	18	10
1¾	3	0	12	1	11	0	8	15	12	20	0	21	4
2	3	3	21	1	19	1	14	22	6	27	0	31	4
2¼	4	0	26	2	2	1	8	30	2	32	8	41	4
2½	5	0	5	2	10	1	22	46	2	50	15	51	4
2¾	5	1	19	2	14	0	22	55	10	68	8	80	10
3	6	0	20	3	1	3	4	73	8	85	5	88	12
3½	7	1	14	3	13	3	0	101	0	121	0	129	0
4	8	2	0	4	5	0	0	126	0	144	0	158	0

TABLE.

Pitch of the Whitworth Taps and Dies for Gas Tubing.

Internal Diameter of Pipe.	External Diameter of Pipe.	Number of Threads per Inch.	Internal Diameter of Pipe.	External Diameter of Pipe.	Number of Threads per Inch.
$\frac{1}{8}$	·385	28	2	2·347	11
$\frac{1}{4}$	·520	19	$2\frac{1}{8}$	2·467	11
$\frac{3}{8}$	·665	19	$2\frac{1}{4}$	2·587	11
$\frac{1}{2}$	·882	14	$2\frac{3}{8}$	2·794	11
$\frac{3}{4}$	1·034	14	$2\frac{1}{2}$	3·001	11
1	1·302	11	$2\frac{5}{8}$	3·124	11
$1\frac{1}{8}$	1·492	11	$2\frac{3}{4}$	3·247	11
$1\frac{1}{4}$	1·650	11	$2\frac{7}{8}$	3·367	11
$1\frac{3}{8}$	1·745	11	3	3·485	11
$1\frac{1}{2}$	1·882	11	$3\frac{1}{4}$	3·698	11
$1\frac{5}{8}$	2·021	11	$3\frac{1}{2}$	3·912	11
$1\frac{3}{4}$	2·047	11	$3\frac{3}{4}$	4·125	11
$1\frac{7}{8}$	2·245	11	4	4·339	11

Uniformity in the screws or threads of service-pipes and fittings is greatly to be desired, a large proportion of the leakage being due to the want of this. The screwed joint may be too slack, in which case leakage often follows; on the other hand, when a socket is too small to receive the screwed end of a pipe, instead of running the tap into the one, or the dies over the other, careless workmen are often content to let the joint pass, provided they succeed in getting a single thread to bite. The natural settlement of the ground, the traffic over the surface, or the first keen frost, disjoints the connection and an escape follows.

To Calculate the Required Size of Service-Pipes.—The following table gives the theoretical diameter required for pipes which have to supply a certain number of burners at distances from the street main. The table is calculated by the formula,—

$d = \sqrt{\dfrac{Q^2 s l}{(1850)^2 h}}$, being the same as that used in the determination

of the quantities of gas delivered by large pipes.

As, however, the actual discharge from small pipes is less than the calculated quantity, the tabular number must be increased by one-

third if the service-pipe is of lead, and by one-half if of wrought iron. When of the latter material, it is not advisable to put in the ground a pipe of less than $\frac{3}{4}$ inch in diameter.

EXAMPLE *of the Manner of Using the Table.*—Supposing there are 40 lights to be supplied at the distance of 70 feet from the main, the tabular number opposite 70 and under 40 is ·78540. To this add one-third if a lead service, making ·98053, and one-half if a wrought-iron service, making 1·10310. The sizes of pipes next above the numbers are 1 inch and $1\frac{1}{4}$ inch respectively, and these are the sizes required.

TABLE

Showing the Internal Diameter of Pipes, in Decimals of an Inch, to Supply Lights at Certain Distances from the Main.

Distance of Lights from Main in Feet.	Number of Lights, each Burning Five Feet per Hour, with a Pressure of One Inch.						
	3.	5.	10.	15.	20.	25.	30.
5	·15457	·18882	·24912	·29424	·32876	·35946	·38824
10	·17682	·21691	·28617	·33660	·37765	·41291	·44415
15	·19176	·23524	·31034	·36504	·40956	·44779	·48167
20	·20311	·24916	·32872	·38666	·43381	·47429	·51019
30	·22027	·27020	·35649	·41932	·47045	·51438	·55329
40	·23331	·28620	·37760	·44415	·49830	·54483	·58605
50	·24396	·29927	·39483	·46441	·52105	·56970	·61280
60	·25302	·31024	·40950	·48167	·54041	·59086	·63556
70	·26094	·32010	·42231	·49675	·55733	·60936	·65546
80	·26802	·32876	·43375	·51255	·57241	·62585	·67011
90	·27439	·33660	·44408	·52235	·58606	·64077	·68925
100	·28023	·34377	·45354	·53348	·59854	·65442	·70393
150	·30391	·37281	·49185	·57054	·64909	·70970	·76339
200	·32191	·39489	·52098	·61281	·68753	·75173	·80860
250	·33660	·41291	·54476	·64077	·71891	·78604	·84550
300	·34901	·42825	·56507	·66457	·74561	·81523	·87691

Distance of Lights from Main in Feet.	Number of Lights, each Burning Five Feet per Hour, with a Pressure of One Inch.					
	40.	50.	100.	150.	200.	300.
5	·43381	·47430	·62577	·73911	·82581	·97525
10	·49832	·54484	·71881	·83775	·94862	1·1157
15	·54041	·59086	·77954	·91693	1·0288	1·2099
20	·57241	·62585	·82571	·97123	1·0897	1·2815
30	·62076	·67872	·89546	1·0533	1·1817	1·3898
40	·65753	·71891	·94848	1·1156	1·2517	1·4721
50	·68753	·75172	·99177	1·1665	1·3089	1·5393
60	·71307	·77928	1·0286	1·2099	1·3574	1·5965
70	·73540	·80405	1·0608	1·2478	1·3999	1·6464
80	·75530	·82582	1·0895	1·2874	1·4378	1·6910
90	·77331	·84550	1·1155	1·3121	1·4721	1·7313
100	·78978	·86351	1·1394	1·3400	1·5035	1·7681
150	·85649	·93688	1·2356	1·4532	1·6805	1·9175
200	·90720	·99191	1·3088	1·5393	1·7270	2·0311
250	·94862	1·0371	1·3685	1·6095	1·8058	2·1238
300	·98389	1·0757	1·4197	1·6693	1·8729	2·2540

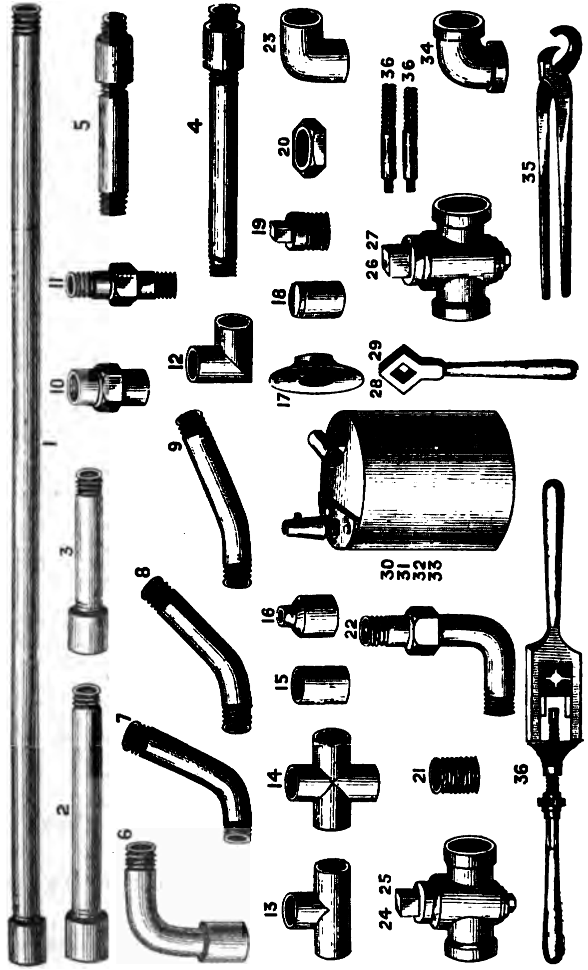

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FIG. 123.

PRICE LIST OF WROUGHT-

No.	Internal Diameter. Inches.	1/8	1/4	3/8	1/2	3/4	1
		s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1	Tubes, 2 to 14 feet long, per foot	0 2	0 2½	0 3	0 4½	0 6	0 8½
2	Pieces, 12 to 23½ inches long, each	0 4	0 5	0 7	0 9	1 0	1 4
3	Do. 3 to 11½ „ „	0 2	0 3	0 4	0 6	0 8	0 11
4	Longscrews, 12 to 23½ „ „	0 5	0 7	0 9	0 11	1 2	1 6
5	„ 3 to 11½ „ „	0 4	0 5	0 6	0 8	0 10	1 0
6	Bends . . . . „	0 5½	0 6½	0 7	0 8	0 11	1 3
7 8 9	Springs, not Socketed . . „	0 4	0 5	0 6	0 7	0 9	0 11
10 11	Socket Union (10), Pipe Do. (11)	..	2 0	2 6	3 0	4 0	5 6
12	Elbows, Wrought-Iron . . .	0 6	0 6½	0 7	0 8	0 10	1 2
13	Tees „ . . .	0 6	0 6½	0 7	0 9	1 0	1 3
14	Crosses „ . . .	0 10	1 0	1 0	1 5	1 9	2 3
15	Plain Sockets	0 1½	0 1½	0 2	0 3	0 3½	0 4
16	Diminished Sockets	..	0 3	0 4	0 5	0 6	0 7
17	Flanges	0 8	0 9	0 10	1 0	1 2	1 4
18 19	Caps (18), Plugs (19)	0 2	0 3	0 3	0 4	0 5	0 6
20 21	Backnuts (20), Nipples (21) . .	0 1	0 2	0 2	0 3	0 3½	0 4
22	Union Bends	..	2 6	3 0	3 9	5 0	6 3
23	Round Elbows, Wrought-Iron .	0 7	0 7	0 8	0 9	1 0	1 4
24	Iron Main Cocks	2 3	2 3	2 9	3 6	4 6	6 6
25	Do. with Brass Plugs	..	..	4 6	5 6	7 6	10 6
26	Round Way Iron Cocks . . .	..	..	3 6	4 0	5 6	7 6
27	Do. with Brass Plugs	..	..	5 0	6 6	9 0	13 0
28	Cock Spanners, Wrought-Iron .	..	..	1 0	1 4	1 8	2 0
29	Do. Malleable Cast-Iron	..	..	0 7	0 8	0 10	1 2
30	Syphon Boxes, 1 Quart . . .	..	..	..	11 0	12 0	13 0
31	Do. 2 „ . . .	..	..	..	..	16 0	17 0
32	Do. 3 „ . . .	..	..	..	..	20 0	22 0
33	Do. 4 „ . . .	..	..	..	..	21 0	23 0
34	Malleable Cast Round Elbows .	0 6	0 6½	0 7	0 8	0 10	1 2

(35) Tongs or Nippers, (36) Stocks, Dies, and Taps, at prices as quoted by the manufacturer.

If Tubes are required to be of longer length than 14 feet, they are charged at the next higher rate.

Tubes of intermediate diameters charged at the price of the next larger size.

Springs; if socketed, sockets added at list prices.

IRON TUBING AND FITTINGS, &c.

1¼		1½		1¾		2		2¼		2½		2¾		3		3½		4	
s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
0	11	1	2	1	6	1	9	2	7	3	3	4	0	4	6	5	6	7	0
1	8	2	0	2	6	3	0	4	6	6	3	7	6	9	0	11	6	14	6
1	1	1	4	2	0	2	3	4	0	4	9	6	0	7	0	8	0	9	0
2	0	2	6	3	3	4	0	5	6	7	0	8	6	10	0	12	6	15	6
1	3	2	0	2	6	3	0	4	6	5	6	6	6	7	6	8	6	10	0
1	9	2	3	3	3	4	3	6	6	10	0	12	0	16	0	25	0	32	6
1	4	1	8	2	6	3	3	5	6	7	6	10	0	12	0	19	0	26	0
6	9	8	0	9	0	10	0	12	0	14	0	16	0	18	0	22	0	28	0
1	9	2	3	3	0	3	6	5	6	8	6	11	0	14	0	22	0	28	0
1	9	2	6	3	0	3	9	6	0	9	6	12	6	16	6	24	0	30	0
3	0	3	6	4	6	5	3	10	6	16	0	21	0	30	0	42	0	50	0
0	6	0	7	0	9	1	0	1	6	2	6	3	0	3	6	5	0	6	0
0	9	0	11	1	1	1	3	2	0	3	0	4	0	5	0	7	0	9	0
1	6	1	9	2	0	2	6	3	9	5	0	6	9	8	6	10	0	11	6
0	8	0	10	1	0	1	3	2	0	2	6	3	6	4	9	7	0	10	0
0	6	0	8	0	10	1	0	1	9	2	3	3	0	3	6	4	6	5	6
8	6	10	0	11	6	13	6	16	0	19	0	22	0	25	0	30	0	36	0
1	11	2	6	3	4	3	10	6	6	10	0	18	0	16	0	25	0	32	0
8	6	11	0	14	0	18	0	27	0	36	0	44	0	50	0	75	0	90	0
15	0	19	6	25	0	32	0	47	0	60	0	90	0	110	0	140	0	190	0
10	0	13	0	17	6	22	0	38	0	54	0	62	0	70	0	100	0	160	0
19	0	28	0	36	0	42	0	60	0	85	0	105	0	120	0	180	0	280	0
2	4	3	0	3	6	4	0	4	9	6	0	7	6	9	0	12	0	14	0
1	8	2	2	2	9	3	3	4	9	6	0	7	6	9	0	12	0	14	0
14	0	15	0	15	6	16	0	18	0	..		..		..		..		..	
18	0	19	0	21	0	23	0	25	0	30	0	35	0	40	0	..		..	
24	0	25	0	26	6	28	0	32	0	35	0	40	0	45	0	50	0	56	0
25	0	27	0	29	0	31	0	34	0	38	0	42	0	47	0	54	0	60	0
1	9	2	3	3	0	3	6	5	6	9	0	12	0	15	0	30	0	40	0

Discount:
- Gas tubes and fittings, per cent.
- Galvanized do. do.
- Steam and water do. do.
- Galvanized do. do.

Iron Cocks over 2 inches at special discounts.

PUBLIC LIGHTING.

The height of a lamp pillar or column (Fig. 124), measured from

FIG. 124.

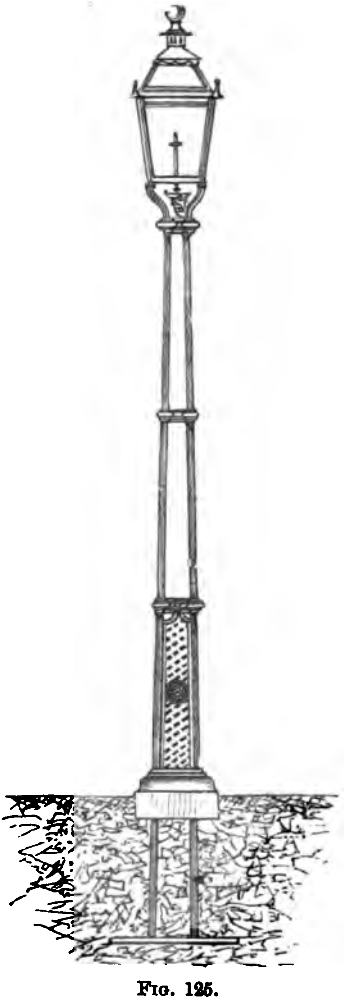


FIG. 125.

the surface of the ground to the centre of the flame, should not exceed 10 feet.

A $\frac{3}{8}$-inch or even a $\frac{1}{2}$-inch lead pipe is not suitable for placing in the interior of a lamp column. In cold districts, in winter, the condensed moisture in a pipe of this small bore becomes frozen, filling up the entire length with solid ice in a very short space of time. This is probably due to the wavy irregularities in the pipe preventing the water from draining rapidly away.

Galvanized wrought-iron pipe is best for lamp columns, and for placing against a wall for the supply of a bracket lamp; and $\frac{1}{2}$-inch is the smallest size that should be used. In situations exposed to cutting winds, and where the frost is keen, $\frac{3}{4}$-inch wrought-iron pipes are best.

If the service-pipe at the entrance to the base of a lamp column has not very ample fall to the main, the water of condensation, unable to drain quickly away, will inevitably be frozen at that point during frost, and, by accretion, will eventually interrupt the passage of the gas.

It is not unusual to find one-half the public lights in some districts extinguished at night when a severe frost prevails. This is simply due to mismanagement, as it would not occur if attention were paid to the matters indicated above.

Seventy yards is the maximum distance apart at which public lamps should be placed.

A new and entirely novel form of lamp post (Fig. 125) has been introduced by J. & J. Braddock. It consists of four 1-inch wrought-iron tubes held together at three points, in addition to the base, by cast-iron binders, one of the tubes being used as the service-pipe for conveying the gas to the burner. Panels may be fixed at the foot, or it can be left open, as desired. No ladder-arm is required, as the tubes, on any side, form a square support for a ladder to rest against. The tubes are continued down through the visible base, and are screwed into a cast-iron plate underground. Altogether, the standard has a neat appearance, and, owing to its lightness—under 2 cwt.—and the ease with which it can be taken to pieces and set up again, it is specially adapted for export.

The ordinary four-sided lamp is the most serviceable for general use. It is 14 inches square at the widest part, and made of tinned copper.

The street lamps designed by Mr. Sugg (Fig. 126) and Mr. Bray (Figs. 127 and 128), with clusters of flat-flame burners, and the lamp and regenerative burner of Herr F. Siemens (Fig. 129) have much

improved the lighting of streets and squares wherever they have been introduced; and have proved, at the same time, that efficient street

FIG. 126.

FIG. 127.

illumination by means of gas is perfectly attainable where there is a willingness on the part of towns' authorities to incur the expense.

The earlier street lamps were constructed with opaque reflecting tops, and the glazed tops were afterwards introduced as an improve-

FIG. 128.

FIG. 129.

ment. When the whole of the light is reflected downwards, the fronts of the houses, except for a short space above the height of the lamp column, are placed in a state of utter darkness, and to passengers

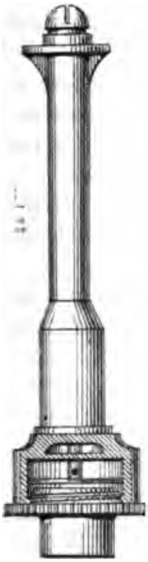


FIG. 130.

walking along the streets the gloomy canopy overhead, rendered all the more sombre and distressing from the concentrated light underneath, has an unearthly and depressing effect.

On the other hand, where the main thoroughfares of a large town are lighted with the capacious lamps above described, with semi-transparent crowns, admitting of the radiation of a portion of the light on the house fronts, the effect is pleasing and satisfactory.

The incandescent gas-light is growing in vogue for street lighting, and nothing in artificial illumination can exceed it either as regards efficiency or economy, provided due care and intelligence are exercised in settling the design of the lamp with a view to controlling the air supply, and in applying the adjustment necessary to counteract the effects of vibration caused by traffic.

Those produced by the Denayrouze Light Syndicate are of a remarkable type, as giving the highest illuminating duty per cubic foot of gas yet attained. They are specially constructed and largely in use for lighting public streets, squares, and other wide areas. The burners are admirably adapted for ranging in groups or clusters, and give excellent results in this way, the groups being in two, three, five, and eight lights, with a consumption per burner varying from eight to ten cubic feet.

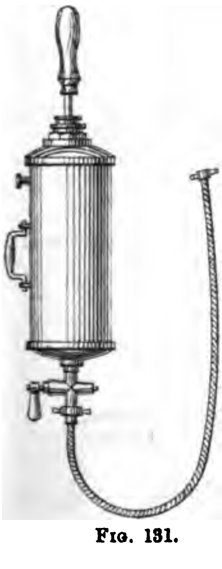


FIG. 131.

The square at the bottom of the usual form of lamp is generally in two or three parts, one of them being hinged on the outer edge, for raising when the lamp has been lighted by the pole. It is a common occurrence to find a portion of the bottom missing altogether, and the flame, thus exposed to the action of the wind, is in a state of constant oscillation, whereby much of the illuminating power of the gas is sacrificed.

The supply of gas to ordinary public lamps is usually fixed at 5 cubic feet per hour for

common gas up to 17 candles value; for cannel gas up to 30 candles value, the supply per hour varies from 4 to 3 cubic feet.

A regulator to each lamp is a necessity in order to secure this measured supply or a near approximation to it; and not less so to obtain the best illuminating effect from the gas. Borradaile's regulator, which is well known, is shown in section in Fig. 130.

Hutchinson Bros.' lamp service cleaner (Fig. 131) is a handy instrument, easily applied, for clearing out obstructions of all kinds, both from services and fittings.

Satisfactory public lighting, as between gas companies and local authorities, is best secured by the adoption of a good average meter system, and the application of a regulator to every lamp.

Weight and Thickness of Glass for Public Lamps.

No. of the Glass or Weight in Ounces per Square Foot	Thickness in Decimals of an Inch.	No. of the Glass or Weight in Ounces per Square Foot.	Thickness in Decimals of an Inch.
12	·059	21	·100
13	·068	24	·111
15	·071	26	·125
16	·077	32	·154
17	·083	36	·167
19	·091	42	·200

Rule to find the Length of Day and Night.

Day.—The hour of sunset, doubled, is the length of the day.
Night.—The hour of sunrise, doubled, is the length of the night.

Rule to find the Hours of Sunrise and Sunset.

Deduct the hour of sunset from 12; the difference is the hour of sunrise and *vice versa.*

The Moon's Rising and Setting.

At 4	days old,	the Moon	sets	about	10	o'clock	at night.
At 5	„	„	„	„	11	„	„
At 6	„	„	„	„	12	„	„
At 7	„	„	„	„	1	o'clock	in the morning.
At 15	„	„	the Moon rises	„	6	„	in the evening.
At 16	„	„	„	„	7½	„	„
At 17	„	„	„	„	8½	„	„
At 18	„	„	„	„	10	„	at night.
At 19	„	„	„	„	11	„	„
At 20	„	„	„	„	12	„	

TABLE

Showing the Consumption of Gas by One Burner per Month, and for the Twelve Months, during the Average Hours of Burning from Sunset throughout the Year.

Month.	Average Time of Sunset.	Mean Duration of Hours of Burning.	Number of Hours of Night per Month.	Consumption of Gas by One Burner per Month, and for the whole Year. Public Street Lamps assumed to be Lighted from Sunset to Sunrise, and Private Lamps from Sunset until Nine o'Clock.									
				3 Cubic Feet per Hour.		3½ Cubic Feet per Hour.		4 Cubic Feet per Hour.		4½ Cubic Feet per Hour.		5 Cubic Feet per Hour.	
				Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.	Public Lamps.	Private Lamps.
	h. m.	h. m.	h.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.	c. ft.
January . .	4 13	16 31	512	1536	445	1792	519	2048	594	2304	668	2560	742
February .	5 7	14 41	411	1233	326	1438	380	1644	436	1850	490	2055	544
March . .	6 6	12 19	382	1146	270	1337	315	1528	360	1719	405	1910	450
April . . .	6 57	9 50	295	885	185	1032	216	1180	246	1327	277	1475	308
May . . .	7 46	7 48	242	726	115	847	134	968	154	1089	173	1210	191
June . . .	8 16	6 30	195	585	..	683	..	780	..	878	..	975	..
July . . .	8 2	7 0	217	651	..	760	..	868	..	976	..	1085	..
August . .	7 16	9 54	307	921	162	1074	190	1228	216	1382	242	1535	268
September .	6 20	11 30	345	1035	240	1207	280	1380	320	1552	360	1425	400
October . .	5 21	13 35	421	1263	340	1474	396	1684	453	1895	509	2105	566
November .	4 25	15 46	473	1419	413	1655	481	1892	550	2128	619	2665	688
December .	3 49	17 0	527	1581	483	1845	564	2108	644	2372	725	2635	803
Total for the year.	..	..	4327	12,981	2979	15,144	3475	17,308	3973	19,472	4468	21,635	4960

TABLE

Showing the Number of Hours during which Gas is usually Burned in each Month, Quarter, and Year, according to the Times of Lighting and Extinguishing.

Times of Lighting and Extinguishing.	Lady-Day Quarter.			Midsummer Quarter.			Michaelmas Quarter.			Christmas Quarter.			Lady-Day.	Midsummer.	Michaelmas.	Christmas.	Total of Year.*
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.					
If lighted at dusk and extinguished at—																	
6 p.m. . . .	65	33	4	..	..	..	..	..	2	31	62	80	102	..	2	173	277
7 „ . . .	96	61	31	4	..	..	..	14	22	62	92	111	188	4	36	265	493
8 „ . . .	127	89	62	28	4	..	..	40	52	93	122	142	278	32	92	357	759
9 „ . . .	158	117	93	58	29	8	13	71	82	124	152	173	368	95	166	449	1078
10 „ . . .	189	145	124	88	60	38	44	102	112	155	182	204	458	186	258	541	1443
11 „ . . .	220	173	155	118	91	68	75	133	142	186	212	235	548	277	350	633	1808
12 „ . . .	251	201	186	148	122	98	106	164	172	217	242	266	638	368	442	725	2173
All night . .	512	411	382	295	242	195	217	307	345	421	473	527	1305	732	869	1421	4327
Lighted at—																	
4 a.m. till d'ylight	137	98	71	28	2	..	..	16	48	80	110	137	306	30	64	327	727
5 „ „	106	70	40	8	..	..	..	..	18	49	80	106	216	8	18	235	472
6 „ „	75	42	9	..	..	..	..	..	..	18	50	75	126	..	..	143	269
7 „ „	44	14	..	..	..	..	..	..	..	..	20	44	58	..	..	64	122

* A deduction of one-sixth may be made for moonlight nights; and in the case of private lamps not being lighted on Sundays, deduct one-seventh.

CONSUMERS' GAS METERS.

Gas Meters are either "Wet" (Figs. 132 and 133), or "Dry" (Figs. 134 and 135).

The wet meter has a measuring wheel or drum enclosed in an iron case charged with water up to a certain level, called the "water-line."

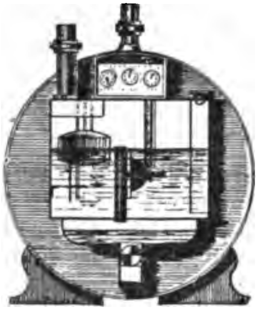


Fig. 132.

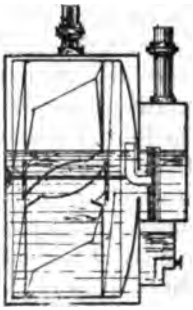


Fig. 133.

The drum is divided into compartments similar to the station meter; and the measurement and indication, or registration, of the gas passing through it are performed in the same manner.

The dry meter has usually a case of tinned iron. This is divided into compartments by a central partition and two or more moveable

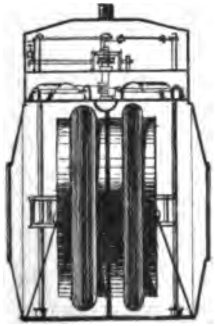


Fig. 134.

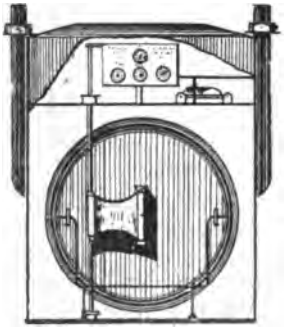


Fig. 135.

diaphragms with prepared flexible leather sides. The gas enters and leaves these compartments alternately through valves whose passages are made to open and close at the proper moment. The alternate expansion and contraction of the inner and outer spaces (after the

now altogether inadmissible; and even two-light meters should only be sparingly used. The low price at which gas is sold encourages its extended consumption; and the houses are becoming fewer in number every day where this small size is sufficient to afford an adequate supply, at reasonable pressures, to the quantity of lights in regular use.

The regular periodical inspection of meters is a point of the utmost importance, and ought never to be neglected. The indices of meters in dwelling-houses, &c., should be noted, and water supplied to the proper level wherever deficient, at least *once every six weeks.* The meters in mills, manufactories, and large establishments of every kind where the consumption of gas is heavy, should be inspected for the like purpose *once every fourteen days.*

The Inspector should always be provided with a supply of leather washers for the different screws and plugs, to replace any that are worn out.

Meters in cold and exposed positions should be protected by a suitable covering during frost, to prevent interruption to the supply of gas by the water becoming frozen. Woollen rags or wrappings of any kind will answer the purpose.

Greenall and Heaton's "Positive" Meter (Fig. 188) differs in construction from those above described. The meter has two measuring

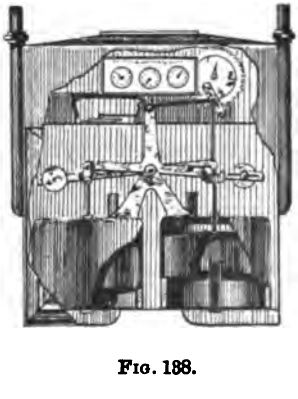


FIG. 188.

cylinders, each divided into two separate chambers by a hollow cylindrical piston, sealed with glycerine within the annular space between the inner and outer parts of the cylinders. The chambers are connected by the gas-ways to the respective valve ports. The

length of the stroke of the pistons is fixed and definite, so that the displacement of gas at each stroke is the same and does not vary. One piston is set half a stroke in advance of the other, and thus each carries the other over the centre. The glycerine seal is not affected by the initial pressure, but only by the slight differential pressures above and below the pistons: In other words, only the slight pressure which is required to actuate the meter.

The motive power meter is but rarely required; but it is exceedingly useful in certain positions, where the pressure, from some unavoidable cause, is insufficient to afford an adequate supply of gas. In construction it is like an ordinary meter, but instead of the gas pressure being the motive power, the gas is exhausted from the main by the measuring wheel. This is set in motion by a descending weight, attached to which is a cord wound on a drum revolving in bearings on the top of the meter case, the drum being geared to the shaft of the measuring wheel, which projects through the back of the case. The speed of the meter, and consequently the pressure of gas obtained, are regulated by the weight aforementioned. Parkinson's motive power meter is shown in Fig. 139.

FIG. 139.

The "prepayment" or "slot" meter, of which there are various forms, is an ingenious device for extending the sale of gas amongst small consumers. By the addition of a simple mechanism contained in a box attached to the ordinary wet or dry meter, and on dropping a penny through a slot therein, a quantity of gas of the value of the penny is allowed to pass to the burner. When the gas thus paid for is consumed, the supply ceases until another prepayment is made.

By another arrangement, on prepayment of a given sum—say 4d. for 100 cubic feet—an extra dial on the meter is set to pass the quantity of gas; and when this is consumed, a valve shuts off the supply, unless, in the meantime, a further payment has been made, and the dial is reset.

Variations in the dimensions of unions for equal sized meters are a source of expense in the case of changing from one make to another.

The Board of Trade in their Annual Report for 1888 suggested that the unions of gas meters throughout the trade should be made of uniform size, and the following table gives the dimensions proposed.

TABLE.

Sizes of Meter Unions as suggested by the Board of Trade in 1888.

	Size of Meter Union.						
	Boss.			Cap.			Lining.
Size of Meter.	Mean Diameter of External Screw.	No. of Threads per inch. Whitworth.	Internal Diameter.	Mean Diameter of Internal Screw.	No. of Threads per inch. Whitworth.	Height of Cap.	External Diameter to enter Boss.
Lights.	Inches.		Inches.	Inches.		Inches.	Inches.
0	0·70	19	0·50	0·66	19	0·40	0·50
1	0·88	19	0·57	0·84	19	0·40	0·55
2	0·88	19	0·57	0·84	19	0·40	0·55
3	0·98	19	0·69	0·94	19	0·50	0·65
5	1·15	14	0·83	1·10	14	0·50	0·81
10	1·45	11	1·05	1·40	11	0·60	1·03
20	1·80	11	1·42	1·75	11	0·60	1·40
30	2·05	11	1·55	2·00	11	0·70	1·53
50	2·25	11	1·80	2·20	11	0·70	1·75
60	2·45	11	2·00	2·40	11	0·80	1·98
80	3·00	11	2·30	2·95	11	1·00	2·28
100	3·00	11	2·30	2·95	11	1·00	2·28
150	3·68	9	3·05	3·65	9	1·20	3·03

Testing Meters.—For the verification of gas meters by a public Inspector under the "Sales of Gas Act," a somewhat elaborate set of apparatus is required.

For ordinary use in testing meters in a gas-works, the following may be provided (see Fig 140):—A standard gasholder of 10 cubic feet capacity. A proving bench. An overhead water cistern. A float of lights, and thermometers for taking the temperature of the air and water.

In testing, it is important to secure uniformity in the temperature of the air or gas in the test holder, the water in the tank, and the air in the room—viz., 60° Fahr.; otherwise corrections for varying temperature have to be made.

Place the meter to be tested on the proving bench, charge it with water to the proper water-line (if a wet meter), and connect it with the holder and to the float of lights (if gas is being used).

See that the pointer of the small metal drum above the index in the

wet meter, or of the small circle on the index plate of the dry meter, coincides with one of the figures marked thereon. If it does not, pass a quantity of gas through till the necessary adjustment is effected.

Next, fill up the test holder till the 0 line of the scale upon it is exactly opposite its pointer.

This being done, turn on the gas or air, and allow the meter to work till the small metal drum has made one or more revolutions, taking

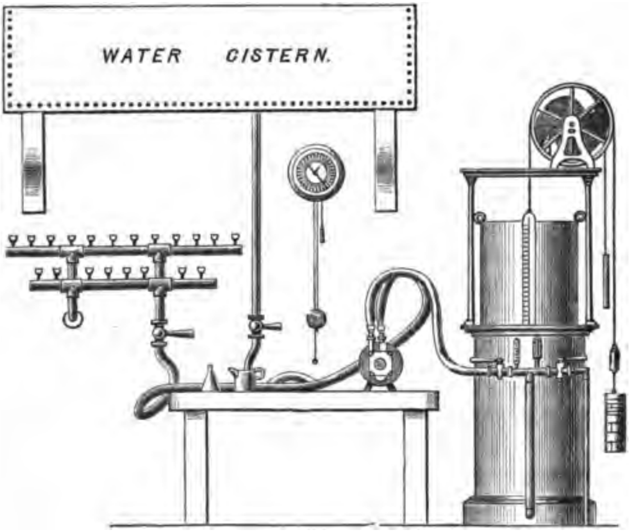


FIG. 140.

care to close the stop-cock when the pointer of the drum is exactly over the figure from which the start was made.

The meter registration is then compared with that of the holder scale. If they correspond, the meter is exactly correct; but if the scale on the holder indicates less or more than the small drum on the meter, the percentage of error is calculated ; or it can be ascertained on reference to the Table.

TABLE.

Showing the Percentage of Error in Meters according as their Registration differs from the Indications of the Test Gasholders.

The sign + is used to indicate *fast*, and − to indicate *slow*.
Meters not exceeding 2 per cent. fast, or 3 per cent. slow, are correct within the meaning of the "Sales of Gas Act."

Meter Registering 1 Foot.		Meter Registering 2 Feet.		Meter Registering 3 Feet.		Meter Registering 3 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Foot.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
0·90	+ 11·11	1·80	+ 11·11	2·70	+ 11·11	3·10	− 3·22
·91	+ 9·89	·81	+ 10·50	·71	+ 10·70	·11	− 3·54
·92	+ 8·70	·82	+ 9·89	·72	+ 10·30	·12	− 3·85
·93	+ 7·25	·83	+ 9·29	·73	+ 9·89	·13	− 4·16
·94	+ 6·36	·84	+ 8·70	·74	+ 9·49	·14	− 4·46
·95	+ 5·26	·85	+ 8·11	·75	+ 9·09	·15	− 4·76
·96	+ 4·17	·86	+ 7·53	·76	+ 8·70	·16	− 5·06
·97	+ 3·09	·87	+ 6·95	·77	+ 8·31	·17	− 5·36
·98	+ 2·04	·88	+ 6·38	·78	+ 7·92	·18	− 5·66
·99	+ 1·01	·89	+ 5·82	·79	+ 7·53	·19	− 5·85
1·00	Nil.	1·90	+ 5·26	2·80	+ 7·14	3·20	− 6·25
·01	− 1·00	·91	+ 4·71	·81	+ 6·76	·21	− 6·54
·02	− 1·97	·92	+ 4·17	·82	+ 6·38	·22	− 6·82
·03	− 2·92	·93	+ 3·63	·83	+ 6·01	·23	− 7·12
·04	− 3·85	·94	+ 3·09	·84	+ 5·63	·24	− 7·41
·05	− 4·74	·95	+ 2·56	·85	+ 5·26	·25	− 7·70
·06	− 5·66	·96	+ 2·04	·86	+ 4·89	·26	− 7·98
·07	− 6·54	·97	+ 1·52	·87	+ 4·53	·27	− 8·26
·08	− 7·40	·98	+ 1·01	·88	+ 4·17	·28	− 8·54
·09	− 8·26	·99	+ 0·50	·89	+ 3·81	·29	− 8·82
1·10	− 9·10	2·00	Nil.	2·90	+ 3·45	3·30	− 9·09
·11	− 9·91	·01	− 0·50	·91	+ 3·09	·31	− 9·36
·12	− 10·07	·02	− 0·99	·92	+ 2·74	·32	− 9·64
		·03	− 1·48	·93	+ 2·39	·33	− 9·91
		·04	− 1·96	·94	+ 2·04	·34	− 10·18
		·05	− 2·44	·95	+ 1·69		
		·06	− 2·91	·96	+ 1·35		
		·07	− 3·38	·97	+ 1·01		
		·08	− 3·85	·98	+ 0·67		
		·09	− 4·31	·99	+ 0·33		
		2·10	− 4·76	3·00	Nil.		
		·11	− 5·21	·01	− 0·33		
		·12	− 5·66	·02	− 0·66		
		·13	− 6·10	·03	− 0·99		
		·14	− 6·54	·04	− 1·32		
		·15	− 6·98	·05	− 1·64		
		·16	− 7·41	·06	− 1·96		
		·17	− 7·83	·07	− 2·28		
		·18	− 8·26	·08	− 2·60		
		·19	− 8·68	·09	− 2·91		

Meter Registering 5 Feet.		Meter Registering 5 Feet.		Meter Registering 5 Feet.		Meter Registering 10 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
4·50	+ 11·11	5·02	− 0·40	5·54	− 9·75	9·00	+ 11·11
·51	+ 10·86	·03	− 0·60	·55	− 9·91	·01	+ 10·99
·52	+ 10·62	·04	− 0·79	·56	− 10·07	·02	+ 10·86
·53	+ 10·38	·05	− 0·99	·57	− 10·23	·03	+ 10·74
·54	+ 10·13	·06	− 1·19	·58	− 10·39	·04	+ 10·62
·55	+ 9·89	·07	− 1·38	·59	− 10·55	·05	+ 10·50
·56	+ 9·65	·08	− 1·57	5·60	− 10·71	·06	+ 10·38
·57	+ 9·41	·09	− 1·77	·61	− 10·87	·07	+ 10·25
·58	+ 9·17	5·10	− 1·96	·62	− 11·03	·08	+ 10·13
·59	+ 8·93	·11	− 2·15	·63	− 11·19	·09	+ 10·01
4·60	+ 8·70	·12	− 2·34			9·10	+ 9·89
·61	+ 8·46	·13	− 2·53			·11	+ 9·77
·62	+ 8·23	·14	− 2·72			·12	+ 9·65
·63	+ 7·99	·15	− 2·91			·13	+ 9·53
·64	+ 7·76	·16	− 3·10			·14	+ 9·41
·65	+ 7·53	·17	− 3·29			·15	+ 9·29
·66	+ 7·30	·18	− 3·47			·16	+ 9·17
·67	+ 7·07	·19	− 3·66			·17	+ 9·05
·68	+ 6·84	5·20	− 3·85			·18	+ 8·93
·69	+ 6·61	·21	− 4·03			·19	+ 8·81
4·70	+ 6·38	·22	− 4·21			9·20	+ 8·70
·71	+ 6·16	·23	− 4·40			·21	+ 8·58
·72	+ 5·93	·24	− 4·58			·22	+ 8·46
·73	+ 5·71	·25	− 4·76			·23	+ 8·34
·74	+ 5·49	·26	− 4·94			·24	+ 8·23
·75	+ 5·26	·27	− 5·12			·25	+ 8·11
·76	+ 5·04	·28	− 5·30			·26	+ 7·99
·77	+ 4·82	·29	− 5·48			·27	+ 7·87
·78	+ 4·60	5·30	− 5·66			·28	+ 7·76
·79	+ 4·38	·31	− 5·84			·29	+ 7·64
4·80	+ 4·17	·32	− 6·02			9·30	+ 7·53
·81	+ 3·95	·33	− 6·19			·31	+ 7·41
·82	+ 3·73	·34	− 6·37			·32	+ 7·30
·83	+ 3·52	·35	− 6·54			·33	+ 7·18
·84	+ 3·31	·36	− 6·72			·34	+ 7·07
·85	+ 3·09	·37	− 6·89			·35	+ 6·95
·86	+ 2·88	·38	− 7·06			·36	+ 6·84
·87	+ 2·67	·39	− 7·24			·37	+ 6·72
·88	+ 2·46	5·40	− 7·41			·38	+ 6·61
·89	+ 2·25	·41	− 7·58			·39	+ 6·50
4·90	+ 2·04	·42	− 7·75			9·40	+ 6·38
·91	+ 1·83	·43	− 7·92			·41	+ 6·27
·92	+ 1·63	·44	− 8·09			·42	+ 6·16
·93	+ 1·42	·45	− 8·26			·43	+ 6·04
·94	+ 1·21	·46	− 8·42			·44	+ 5·93
·95	+ 1·01	·47	− 8·59			·45	+ 5·82
·96	+ 0·81	·48	− 8·76			·46	+ 5·71
·97	+ 0·60	·49	− 8·93			·47	+ 5·60
·98	+ 0·40	5·50	− 9·09			·48	+ 5·49
·99	+ 0·20	·51	− 9·26			·49	+ 5·37
5·00	Nil.	·52	− 9·42			9·50	+ 5·26
·01	− 0·20	·53	− 9·59			·51	+ 5·15

Meter Registering 20 Feet.		Meter Registering 20 Feet.		Meter Registering 20 Feet.		Meter Registering 30 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
20·16	− 0·79	21·20	− 5·66	22·24	− 10·07	27·00	+ 11·11
·18	− 0·89	·22	− 5·75	·26	− 10·15	·02	+ 11·03
20·20	− 0·99	·24	− 5·84	·28	− 10·23	·04	+ 10·95
·22	− 1·09	·26	− 5·93	22·30	− 10·31	·06	+ 10·86
.24	− 1·19	·28	− 6·02	·32	− 10·39	·08	+ 10·78
·26	− 1·28	21·30	− 6·10	·34	− 10·47	27·10	+ 10·70
·28	− 1·38	·32	− 6·19	·36	− 10·55	·12	+ 10·62
20·30	− 1·48	·34	− 6·28	·38	− 10·63	·14	+ 10·54
·32	− 1·57	·36	− 6·37	22·40	− 10·71	·16	+ 10·46
·34	− 1·67	·38	− 6·46	·42	− 10·79	·18	+ 10·38
·36	− 1·77	21·40	− 6·54	·44	− 10·87	27·20	+ 10·30
·38	− 1·86	·42	− 6·63	·46	− 10·95	·22	+ 10·21
20·40	− 1·96	·44	− 6·72	·48	− 11·03	·24	+ 10·13
·42	− 2·06	·46	− 6·80	22·50	− 11·11	·26	+ 10·05
·44	− 2·15	·48	− 6·89			·28	+ 9·97
·46	− 2·25	21·50	− 6·98			27·30	+ 9·89
·48	− 2·34	·52	− 7·06			·32	+ 9·81
20·50	− 2·44	·54	− 7·15			·34	+ 9·73
·52	− 2·53	·56	− 7·24			·36	+ 9·65
·54	− 2·63	·58	− 7·32			·38	+ 9·57
·56	− 2·73	21·60	− 7·41			27·40	+ 9·49
·58	− 2·82	·62	− 7·49			·42	+ 9·41
20·60	− 2·91	·64	− 7·58			·44	+ 9·33
·62	− 3·01	·66	− 7·66			·46	+ 9·25
·64	− 3·10	·68	− 7·75			·48	+ 9·17
·66	− 3·19	21·70	− 7·83			27·50	+ 9·09
·68	− 3·29	·72	− 7·92			·52	+ 9·01
20·70	− 3·38	·74	− 8·00			·54	+ 8·93
·72	− 3·47	·76	− 8·09			·56	+ 8·85
·74	− 3·57	·78	− 8·17			·58	+ 8·78
·76	− 3·66	21·80	− 8·26			27·60	+ 8·70
·78	− 3·75	·82	− 8·34			·62	+ 8·62
20·80	− 3·85	·84	− 8·42			·64	+ 8·54
·82	− 3·94	·86	− 8·51			·66	+ 8·46
·84	− 4·03	·88	− 8·59			·68	+ 8·38
·86	− 4·12	21·90	− 8·68			27·70	+ 8·31
·88	− 4·21	·92	− 8·76			·72	+ 8·23
20·90	− 4·31	·94	− 8·84			·74	+ 8·15
·92	− 4·40	·96	− 8·93			·76	+ 8·07
·94	− 4·49	·98	− 9·01			·78	+ 7·99
·96	− 4·58	22·00	− 9·09			27·80	+ 7·92
·98	− 4·67	·02	− 9·18			·82	+ 7·84
21·00	− 4·76	·04	− 9·26			·84	+ 7·76
·02	− 4·85	·06	− 9·34			·86	+ 7·68
·04	− 4·94	·08	− 9·42			·88	+ 7·61
·06	− 5·03	22·10	− 9·51			27·90	+ 7·53
·08	− 5·12	·12	− 9·59			·92	+ 7·45
21·10	− 5·21	·14	− 9·67			·94	+ 7·38
·12	− 5·30	·16	− 9·75			·96	+ 7·30
·14	− 5·39	·18	− 9·83			·98	+ 7·22
·16	− 5·48	22·20	− 9·91			28·00	+ 7·14
·18	− 5·57	·22	− 9·99			·02	+ 7·07

Meter Registering 30 Feet.		Meter Registering 30 Feet.		Meter Registering 30 Feet.		Meter Registering 30 Feet.	
Reading of Scale of Gasholder.	Amount of Error.	Reading of Scale of Gasholder.	Amount of Error.	Reading of Scale of Gasholder.	Amount of Error.	Reading of Scale of Gasholder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
28·04	+ 6·99	29·08	+ 3·16	30·12	− 0·40	31·16	− 3·72
·06	+ 6·92	29·10	+ 3·09	·14	− 0·47	·18	− 3·79
·08	+ 6·84	·12	+ 3·02	·16	− 0·53	31·20	− 3·85
28·10	+ 6·76	·14	+ 2·95	·18	− 0·60	·22	− 3·91
·12	+ 6·69	·16	+ 2·88	30·20	− 0·66	·24	− 3·97
·14	+ 6·61	·18	+ 2·81	·22	− 0·73	·26	− 4·03
·16	+ 6·53	29·20	+ 2·74	·24	− 0·79	·28	− 4·09
·18	+ 6·46	·22	+ 2·67	·26	− 0·86	31·30	− 4·16
28·20	+ 6·38	·24	+ 2·60	·28	− 0·92	·32	− 4·22
·22	+ 6·31	·56	+ 2·53	30·30	− 0·99	·34	− 4·28
·24	+ 6·23	·28	+ 2·46	·32	− 1·06	·36	− 4·34
·26	+ 6·16	29·30	+ 2·39	·34	− 1·12	·38	− 4·40
·28	+ 6·08	·32	+ 2·32	·36	− 1·19	31·40	− 4·46
28·30	+ 6·01	·34	+ 2·25	·38	− 1·26	·42	− 4·52
·32	+ 5·93	·36	+ 2·18	30·40	− 1·32	·44	− 4·58
·34	+ 5·86	·38	+ 2·11	·42	− 1·38	·46	− 4·64
·36	+ 5·78	29·40	+ 2·04	·44	− 1·44	·48	− 4·70
·38	+ 5·71	·42	+ 1·97	·46	− 1·51	31·50	− 4·76
28·40	+ 5·63	·44	+ 1·90	·48	− 1·57	·52	− 4·82
·42	+ 5·56	·46	+ 1·83	30·50	− 1·64	·54	− 4·88
·44	+ 5·49	·48	+ 1·76	·52	− 1·71	·56	− 4·94
·46	+ 5·41	29·50	+ 1·69	·54	− 1·77	·58	− 5·00
·48	+ 5·34	·52	+ 1·63	·56	− 1·83	31·60	− 5·06
28·50	+ 5·26	·54	+ 1·56	·58	− 1·89	·62	− 5·12
·52	+ 5·19	·56	+ 1·49	30·60	− 1·96	·64	− 5·18
·54	+ 5·11	·58	+ 1·42	·62	− 2·02	·66	− 5·24
·56	+ 5·04	29·60	+ 1·35	·64	− 2·09	·68	− 5·30
·58	+ 4·96	·62	+ 1·28	·66	− 2·15	31·70	− 5·36
28·60	+ 4·89	·64	+ 1·21	·68	− 2·22	·72	− 5·42
·62	+ 4·82	·66	+ 1·14	30·70	− 2·28	·74	− 5·48
·64	+ 4·75	·68	+ 1·08	·72	− 2·34	·76	− 5·54
·66	+ 4·67	29·70	+ 1·01	·74	− 2·40	·78	− 5·60
·68	+ 4·60	·72	+ 0·94	·76	− 2·47	31·80	− 5·66
28·70	+ 4·53	·74	+ 0·88	·78	− 2·53	·82	− 5·72
·72	+ 4·45	·76	+ 0·81	30·80	− 2·60	·84	− 5·78
·74	+ 4·38	·78	+ 0·74	·82	− 2·66	·86	− 5·84
·76	+ 4·31	29·80	+ 0·67	·84	− 2·72	·88	− 5·90
·78	+ 4·24	·82	+ 0·60	·86	− 2·78	31·90	− 5·96
28·80	+ 4·17	·84	+ 0·53	·88	− 2·85	·92	− 6·02
·82	+ 4·10	·86	+ 0·47	30·90	− 2·91	·94	− 6·08
·84	+ 4·02	·88	+ 0·40	·92	− 2·97	·96	− 6·13
·86	+ 3·95	29·90	+ 0·33	·94	− 3·04	·98	− 6·19
·88	+ 3·88	·92	+ 0·26	·96	− 3·10	32·00	− 6·25
28·90	+ 3·81	·94	+ 0·20	·98	− 3·16	·02	− 6·31
·92	+ 3·73	·96	+ 0·13	31·00	− 3·22	·04	− 6·37
·94	+ 3·66	·98	+ 0·07	·02	− 3·29	·06	− 6·42
·96	+ 3·59	30·00	Nil.	·04	− 3·35	·08	− 6·48
·98	+ 3·52	·02	− 0·07	·06	− 3·42	32·10	− 6·54
29·00	+ 3·45	·04	− 0·13	·08	− 3·48	·12	− 6·60
·02	+ 3·38	·06	− 0·20	31·10	− 3·54	·14	− 6·66
·04	+ 3·31	·08	− 0·27	·12	− 2·60	·16	− 6·72
·06	+ 3·24	30·10	− 0·33	·14	− 3·66	·18	− 6·77

Meter Registering 30 Feet.		Meter Registering 30 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
32·20	− 6·83	33·24	− 9·75	36·00	+ 11·11	37·04	+ 7·99
·22	− 6·89	·26	− 9·81	·02	+ 11·05	·06	+ 7·93
·24	− 6·95	·28	− 9·86	·04	+ 10·99	·08	+ 7·87
·26	− 7·01	33·30	− 9·91	·06	+ 10·92	37·10	+ 7·82
·28	− 7·07	·32	− 9·96	·08	+ 10·86	·12	+ 7·76
32·30	− 7·12	·34	− 10·01	36·10	+ 10·80	·14	+ 7·70
·32	− 7·18	·36	− 10·07	·12	+ 10·74	·16	+ 7·64
·34	− 7·24	·38	− 10·12	·14	+ 10·68	·18	+ 7·59
·36	− 7·30	33·40	− 10·18	·16	+ 10·62	37·20	+ 7·53
·38	− 7·36	·42	− 10·23	·18	+ 10·56	·22	+ 7·47
32·40	− 7·41	·44	− 10·28	36·20	+ 10·50	·24	+ 7·41
·42	− 7·47	·46	− 10·34	·22	+ 10·44	·26	+ 7·36
·44	− 7·53	·48	− 10·39	·24	+ 10·38	·28	+ 7·30
·46	− 7·59	33·50	− 10·45	·26	+ 10·31	37·30	+ 7·24
·48	− 7·64	·52	− 10·50	·28	+ 10·25	·32	+ 7·18
32·50	− 7·70	·54	− 10·55	36·30	+ 10·19	·34	+ 7·13
·52	− 7·76	·56	− 10·61	·32	+ 10·13	·36	+ 7·07
·54	− 7·82	·58	− 10·66	·34	+ 10·07	·38	+ 7·01
·56	− 7·87	33·60	− 10·71	·36	+ 10·01	37·40	+ 6·95
·58	− 7·93	·62	− 10·76	·38	+ 9·95	·42	+ 6·90
32·60	− 7·98	·64	− 10·82	36·40	+ 9·89	·44	+ 6·84
·62	− 8·04	·66	− 10·87	·42	+ 9·83	·46	+ 6·78
·64	− 8·10	·68	− 10·93	·44	+ 9·77	·48	+ 6·72
·66	− 8·15	33·70	− 10·98	·46	+ 9·71	37·50	+ 6·66
·68	− 8·21	·72	− 11·03	·48	+ 9·65	·52	+ 6·61
32·70	− 8·26	·74	− 11·09	36·50	+ 9·59	·54	+ 6·55
·72	− 8·32	·76	− 11·14	·52	+ 9·53	·56	+ 6·50
·74	− 8·37	·78	− 11·19	·54	+ 9·47	·58	+ 6·44
·76	− 8·43			·56	+ 9·41	37·60	+ 6·38
·78	− 8·49			·58	+ 9·35	·62	+ 6·32
32·80	− 8·54			36·60	+ 9·29	·64	+ 6·27
·82	− 8·60			·62	+ 9·23	·66	+ 6·21
·84	− 8·66			·64	+ 9·17	·68	+ 6·16
·86	− 8·71			·66	+ 9·11	37·70	+ 6·10
·88	− 8·77			·68	+ 9·05	·72	+ 6·04
32·90	− 8·82			36·70	+ 8·99	·74	+ 5·98
·92	− 8·87			·72	+ 8·93	·76	+ 5·93
·94	− 8·93			·74	+ 8·87	·78	+ 5·87
·96	− 8·99			·76	+ 8·81	37·80	+ 5·82
·98	− 9·04			·78	+ 8·76	·82	+ 5·76
33·00	− 9·09			36·80	+ 8·70	·84	+ 5·71
·02	− 9·15			·82	+ 8·64	·86	+ 5·65
·04	− 9·20			·84	+ 8·58	·88	+ 5·60
·06	− 9·26			·86	+ 8·52	37·90	+ 5·54
·08	− 9·31			·88	+ 8·46	·92	+ 5·49
33·10	− 9·36			36·90	+ 8·40	·94	+ 5·43
·12	− 9·42			·92	+ 8·34	·96	+ 5·37
·14	− 9·47			·94	+ 8·29	·98	+ 5·31
·16	− 9·53			·96	+ 8·23	38·00	+ 5·26
·18	− 9·59			·98	+ 8·17	·02	+ 5·20
33·20	− 9·64			37·00	+ 8·11	·04	+ 5·15
·22	− 9·70			·02	+ 8·05	·06	+ 5·09

Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
38·08	+ 5·04	39·12	+ 2·25	40·16	− 0·40	41·20	− 2·91
38·10	+ 4·98	·14	+ 2·20	·18	− 0·45	·22	− 2·96
·12	+ 4·93	·16	+ 2·15	40·20	− 0·50	·24	− 3·01
·14	+ 4·87	·18	+ 2·09	·22	− 0·55	·26	− 3·06
·16	+ 4·82	39·20	+ 2·04	·24	− 0·60	·28	− 3·10
·18	+ 4·76	·22	+ 1·99	·26	− 0·65	41·30	− 3·15
38·20	+ 4·71	·24	+ 1·94	·28	− 0·70	·32	− 3·19
·22	+ 4·65	·26	+ 1·88	40·30	− 0·75	·34	− 3·24
·24	+ 4·60	·28	+ 1·83	·32	− 0·79	·36	− 3·29
·26	+ 4·54	39·30	+ 1·78	·34	− 0·84	·38	− 3·34
·28	+ 4·49	·32	+ 1·73	·36	− 0·89	41·40	− 3·38
38·30	+ 4·44	·34	+ 1·68	·38	− 0·94	·42	− 3·43
·32	+ 4·38	·36	+ 1·63	40·40	− 0·99	·44	− 3·47
·34	+ 4.33	·38	+ 1·57	·42	− 1·04	·46	− 3·52
·36	+ 4·28	39·40	+ 1·52	·44	− 1·09	·48	− 3·57
·38	+ 4·22	·42	+ 1·47	·46	− 1·14	41·50	− 3·61
38·40	+ 4·17	·44	+ 1·42	·48	− 1·19	·52	− 3·66
·42	+ 4·11	·46	+ 1·37	40·50	− 1·24	·54	− 3·71
·44	+ 4·06	·48	+ 1·32	·52	− 1·28	·56	− 3·75
·46	+ 4·00	39·50	+ 1·26	·54	− 1·33	·58	− 3·80
·48	+ 3·95	·52	+ 1·21	·56	− 1·38	41·60	− 3·85
38·50	+ 3·90	·54	+ 1·16	·58	− 1·43	·62	− 3·90
·52	+ 3·84	·56	+ 1·11	40·60	− 1·48	·64	− 3·94
·54	+ 3·78	·58	+ 1·06	·62	− 1·53	·66	− 3·99
·56	+ 3·73	39·60	+ 1·01	·64	− 1·57	·68	− 4·03
·58	+ 3·68	·62	+ 0·96	·66	− 1·62	41·70	− 4·08
38·60	+ 3·63	·64	+ 0·91	·68	− 1·67	·72	− 4·12
·62	+ 3·57	·66	+ 0·86	40·70	− 1·72	·74	− 4·17
·64	+ 3·52	·68	+ 0·81	·72	− 1·77	·76	− 4·21
·66	+ 3·46	39·70	+ 0·75	·74	− 1·82	·78	− 4·26
·68	+ 3·41	·72	+ 0·70	·76	− 1·86	41·80	− 4·31
38·70	+ 3·36	·74	+ 0·65	·78	− 1·91	·82	− 4·36
·72	+ 3·31	·76	+ 0·60	40·80	− 1·96	·84	− 4·40
·74	+ 3·25	·78	+ 0·55	·82	− 2·01	·86	− 4·45
·76	+ 3·20	39·80	+ 0·50	·84	− 2·06	·88	− 4·49
·78	+ 3·14	·82	+ 0·45	·86	− 2·10	41·90	− 4·54
38·80	+ 3·09	·84	+ 0·40	·88	− 2·15	·92	− 4·58
·82	+ 3·04	·86	+ 0·35	40·90	− 2·20	·94	− 4·63
·84	+ 2·99	·88	+ 0·30	·92	− 2·25	·96	− 4·67
·86	+ 2·93	39·90	+ 0·25	·94	− 2·30	·98	− 4·72
·88	+ 2·88	·92	+ 0·20	·96	− 2·34	42·00	− 4·76
38·90	+ 2·82	·94	+ 0·15	·98	− 2·39	·02	− 4·81
·92	+ 2·77	·96	+ 0.10	41·00	− 2·44	·04	− 4·85
·94	+ 2·72	·98	+ 0·05	·02	− 2·49	·06	− 4·90
·96	+ 2·67	40·00	Nil.	·04	− 2·53	·08	− 4·94
·98	+ 2·61	·02	− 0·05	·06	− 2·58	42·10	− 4·99
39·00	+ 2·56	·04	− 0·10	·08	− 2·63	·12	− 5·03
·02	+ 2·51	·06	− 0·15	41·10	− 2·68	·14	− 5·08
·04	+ 2·46	·08	− 0·20	·12	− 2·72	·16	− 5·12
·06	+ 2·40	40·10	− 0·25	·14	− 2·78	·18	− 5·17
·08	+ 2·35	·12	− 0·30	·16	− 2·82	42·20	− 5·21
39·10	+ 2·30	·14	− 0·35	·18	− 2·87	·22	− 5·26

Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 40 Feet.		Meter Registering 50 Feet.	
Reading of Scale of Gasholder.	Amount of Error.	Reading of Scale of Gasholder.	Amount of Error.	Reading of Scale of Gasholder.	Amount of Error.	Reading of Scale of Gasholder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
42·24	− 5·30	43·28	− 7·58	44·32	− 9·75	45·00	+ 11·11
·26	− 5·35	43·30	− 7·62	·34	− 9·79	·02	+ 11·06
·28	− 5·39	·32	− 7·66	·36	− 9·83	·04	+ 11·01
42·30	− 5·44	·34	− 7·71	·38	− 9·87	·06	+ 10·96
·32	− 5·48	·36	− 7·75	44·40	− 9·91	·08	+ 10·91
·34	− 5·53	·38	− 7·79	·42	− 9·95	45·10	+ 10·86
·36	− 5·57	43·40	− 7·83	·44	− 9·99	·12	+ 10·81
·38	− 5·62	·42	− 7·88	·46	− 10·03	·14	+ 10·76
42·40	− 5·66	·44	− 7·92	·48	− 10·07	·16	+ 10·72
·42	− 5·71	·46	− 7·96	44·50	− 10·11	·18	+ 10·67
·44	− 5·75	·48	− 8·00	·52	− 10·15	45·20	+ 10·62
·46	− 5·80	43·50	− 8·05	·54	− 10·19	·22	+ 10·57
·48	− 5·84	·52	− 8·09	·56	− 10·23	·24	+ 10·52
42·50	− 5·88	·54	− 8·13	·58	− 10·27	·26	+ 10·48
·52	− 5·93	·56	− 8·17	44·60	− 10·31	·28	+ 10·43
·54	− 5·98	·58	− 8·22	·62	− 10·35	45·30	+ 10·38
·56	− 6·02	43·60	− 8·26	·64	− 10·39	·32	+ 10·33
·58	− 6·06	·62	− 8·30	·66	− 10·43	·34	+ 10·28
42·60	− 6·10	·64	− 8·34	·68	− 10·47	·36	+ 10·23
·62	− 6·15	·66	− 8·38	44·70	− 10·51	·38	+ 10·18
·64	− 6·19	·68	− 8·42	·72	− 10·55	45·40	+ 10·13
·66	− 6·24	43·70	− 8·47	·74	− 10·59	·42	+ 10·08
·68	− 6·28	·72	− 8·51	·76	− 10·63	·44	+ 10·03
42·70	− 6·33	·74	− 8·55	·78	− 10·67	·46	+ 9·99
·72	− 6·37	·76	− 8·59	44·80	− 10·71	·48	+ 9·94
·74	− 6·41	·78	− 8·64	·82	− 10·75	45·50	+ 9·89
·76	− 6·45	43·80	− 8·68	·84	− 10·79	·52	+ 9·84
·78	− 6·50	·82	− 8·72	·86	− 10·84	·54	+ 9·79
42·80	− 6·54	·84	− 8·76	·88	− 10·87	·56	+ 9·75
·82	− 6·59	·86	− 8·80	44·90	− 10·91	·58	+ 9·70
·84	− 6·63	·88	− 8·84	·92	− 10·95	45·60	+ 9·65
·86	− 6·68	43·90	− 8·89	·94	− 10·99	·62	+ 9·60
·88	− 6·72	·92	− 8·93	·96	− 11·03	·64	+ 9·55
42·90	− 6·76	·94	− 8·97	·98	− 11·07	·66	+ 9.50
·92	− 6·80	·96	− 9·01	45·00	− 11·11	·68	+ 9·46
·94	− 6·85	·98	− 9·05			45·70	+ 9·41
·96	− 6·89	44·00	− 9·09			·72	+ 9·36
·98	− 6·94	·02	− 9·14			·74	+ 9·31
43·00	− 6·98	·04	− 9·18			·76	+ 9·27
·02	− 7·02	·06	− 9·22			·78	+ 9·22
·04	− 7·06	·08	− 9·26			45·80	+ 9·17
·06	− 7·11	44·10	− 9·30			·82	+ 9·12
·08	− 7·15	·12	− 9·34			·84	+ 9·07
43·10	− 7·20	·14	− 9·38			·86	+ 9·03
·12	− 7·24	·16	− 9·42			·88	+ 8·98
·14	− 7·28	·18	− 9·47			45·90	+ 8·93
·16	− 7·32	44·20	− 9·51			·92	+ 8·88
·18	− 7·37	·22	− 9·55			·94	+ 8·84
43·20	− 7·41	·24	− 9·59			·96	+ 8·79
·22	− 7·45	·26	− 9·63			·98	+ 8·75
·24	− 7·49	·28	− 9·67			46·00	+ 8·70
·26	− 7·54	44·30	− 9·71			·02	+ 8·65

Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
46·04	+ 8·60	47·08	+ 6·20	48·12	+ 3·91	49·16	+ 1·71
·06	+ 8·56	47·10	+ 6·16	·14	+ 3·86	·18	+ 1·67
·08	+ 8·51	·12	+ 6·11	·16	+ 3·82	49·20	+ 1·63
46·10	+ 8·46	·14	+ 6·07	·18	+ 3·77	·22	+ 1·59
·12	+ 8·41	·16	+ 6·02	48·20	+ 3·73	·24	+ 1·55
·14	+ 8·37	·18	+ 5·98	·22	+ 3·69	·26	+ 1·50
·16	+ 8·32	47·20	+ 5·93	·24	+ 3·65	·28	+ 1·46
·18	+ 8·28	·22	+ 5·89	·26	+ 3·60	49·30	+ 1·42
46·20	+ 8·23	·24	+ 5·84	·28	+ 3·56	·32	+ 1·38
·22	+ 8·18	·26	+ 5·80	48·30	+ 3·52	·34	+ 1·34
·24	+ 8·13	·28	+ 5·75	·32	+ 3·48	·36	+ 1·29
·26	+ 8·09	47·30	+ 5·71	·34	+ 3·44	·38	+ 1·25
·28	+ 8·04	·32	+ 5·67	·36	+ 3·39	49·40	+ 1·21
46·30	+ 7·99	·34	+ 5·62	·38	+ 3·35	·42	+ 1·17
·32	+ 7·94	·36	+ 5·58	48·40	+ 3·31	·44	+ 1·13
·34	+ 7·90	·38	+ 5·53	·42	+ 3·27	·46	+ 1·09
·36	+ 7·85	47·40	+ 5·49	·44	+ 3·22	·48	+ 1·05
·38	+ 7·81	·42	+ 5·44	·46	+ 3·18	49·50	+ 1·01
46·40	+ 7·76	·44	+ 5·40	·48	+ 3·13	·52	+ 0·97
·42	+ 7·71	·46	+ 5·35	48·50	+ 3·09	·54	+ 0·93
·44	+ 7·67	·48	+ 5·31	·52	+ 3·05	·56	+ 0·89
·46	+ 7·62	47·50	+ 5·26	·54	+ 3·01	·58	+ 0·85
·48	+ 7·58	·52	+ 5·22	·56	+ 2·96	49·60	+ 0·81
46·50	+ 7·53	·54	+ 5·17	·58	+ 2·92	·62	+ 0·77
·52	+ 7·48	·56	+ 5·13	48·60	+ 2·88	·64	+ 0·73
·54	+ 7·44	·58	+ 5·08	·62	+ 2·84	·66	+ 0·68
·56	+ 7·39	47·60	+ 5·04	·64	+ 2·80	·68	+ 0·64
·58	+ 7·35	·62	+ 5·00	·66	+ 2·75	49·70	+ 0·60
46·60	+ 7·30	·64	+ 4·95	·68	+ 2·71	·72	+ 0·56
·62	+ 7·25	·66	+ 4·91	48·70	+ 2·67	·74	+ 0·52
·64	+ 7·21	·68	+ 4·86	·72	+ 2·63	·76	+ 0·48
·66	+ 7·16	47·70	+ 4·82	·74	+ 2·59	·78	+ 0·44
·68	+ 7·12	·72	+ 4·78	·76	+ 2·54	49·80	+ 0·40
46·70	+ 7·07	·74	+ 4·73	·78	+ 2·50	·82	+ 0·36
·72	+ 7·02	·76	+ 4·69	48·80	+ 2·46	·84	+ 0·32
·74	+ 6·98	·78	+ 4·64	·82	+ 2·42	·86	+ 0·28
·76	+ 6·93	47·80	+ 4·60	·84	+ 2·38	·88	+ 0·24
·78	+ 6·89	·82	+ 4·56	·86	+ 2·33	49·90	+ 0·20
46·80	+ 6·84	·84	+ 4·51	·88	+ 2·29	·92	+ 0·16
·82	+ 6·79	·86	+ 4·47	48·90	+ 2·25	·94	+ 0·12
·84	+ 6·75	·88	+ 4·42	·92	+ 2·21	·96	+ 0·08
·86	+ 6·70	47·90	+ 4·38	·94	+ 2·17	·98	+ 0·04
·88	+ 6·66	·92	+ 4·34	·96	+ 2·12	50·00	Nil.
46·90	+ 6·61	·94	+ 4·30	·98	+ 2·08	·02	− 0·04
·92	+ 6·56	·96	+ 4·25	49·00	+ 2·04	·04	− 0·08
·94	+ 6·52	·98	+ 4·21	·02	+ 2·00	·06	− 0·12
·96	+ 6·47	48·00	+ 4·17	·04	+ 1·96	·08	− 0·16
·98	+ 6·43	·02	+ 4·13	·06	+ 1·91	50·10	− 0·20
47·00	+ 6·38	·04	+ 4·08	·08	+ 1·87	·12	− 0·24
·02	+ 6·34	·06	+ 4·04	49·10	+ 1·83	·14	− 0·28
·04	+ 6·29	·08	+ 3·99	·12	+ 1·79	·16	− 0·32
·06	+ 6·25	48·10	+ 3·95	·14	+ 1·75	·18	− 0·36

Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.		Meter Registering 50 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
50·20	– 0·40	51·24	– 2·42	52·70	– 5·12	55·30	– 9·59
·22	– 0·44	·26	– 2·45	·75	– 5·21	·35	– 9·67
·24	– 0·48	·28	– 2·49	·80	– 5·30	·40	– 9·75
·26	– 0·52	51·30	– 2·53	·85	– 5·39	·45	– 9·83
·28	– 0·56	·32	– 2·57	·90	– 5·48	55·50	– 9·91
50·30	– 0·60	·34	– 2·61	·95	– 5·57	·55	– 9·99
·32	– 0·64	·36	– 2·65	53·00	– 5·66	·60	– 10·07
·34	– 0·68	·38	– 2·69	·05	– 5·75	·65	– 10·15
·36	– 0·71	51·40	– 2·72	·10	– 5·84	·70	– 10·23
·38	– 0·75	·42	– 2·76	·15	– 5·93	·75	– 10·31
50·40	– 0·79	·44	– 2·80	·20	– 6·02	·80	– 10·39
·42	– 0·83	·46	– 2·83	·25	– 6·10	·85	– 10·47
·44	– 0·87	·48	– 2·87	·30	– 6·19	·90	– 10·55
·46	– 0·91	51·50	– 2·91	·35	– 6·28	·95	– 10·63
·48	– 0·95	·52	– 2·95	·40	– 6·37	56·00	– 10·71
50·50	– 0·99	·54	– 2·99	·45	– 6·45	·05	– 10·79
·52	– 1·03	·56	– 3·02	53·50	– 6·54	·10	– 10·87
·54	– 1·07	·58	– 3·06	·55	– 6·63	·15	– 10·95
·56	– 1·11	51·60	– 3·10	·60	– 6·72	·20	– 11·03
·58	– 1·15	·62	– 3·14	·65	– 6·80	·25	– 11·11
50·60	– 1·19	·64	– 3·18	·70	– 6·89		
·62	– 1·23	·66	– 3·21	·75	– 6·98		
·64	– 1·27	·68	– 3·25	·80	– 7·06		
·66	– 1·30	51·70	– 3·29	·85	– 7·15		
·68	– 1·34	·72	– 3·33	·90	– 7·24		
50·70	– 1·38	·74	– 3·36	·95	– 7·32		
·72	– 1·42	·76	– 3·40	54·00	– 7·41		
·74	– 1·46	·78	– 3·43	·05	– 7·49		
·76	– 1·49	51·80	– 3·47	·10	– 7·58		
·78	– 1·53	·82	– 3·51	·15	– 7·66		
50·80	– 1·57	·84	– 3·55	·20	– 7·75		
·82	– 1·61	·86	– 3·58	·25	– 7·83		
·84	– 1·65	·88	– 3·62	·30	– 7·92		
·86	– 1·69	51·90	– 3·66	·35	– 8·00		
·88	– 1·73	·92	– 3·70	·40	– 8·09		
50·90	– 1·77	·94	– 3·74	·45	– 8·17		
·92	– 1·81	·96	– 3·77	54·50	– 8·26		
·94	– 1·85	·98	– 3·81	·55	– 8·34		
·96	– 1·88	52·00	– 3·85	·60	– 8·42		
·98	– 1·92	·05	– 3·94	·65	– 8·51		
51·00	– 1·96	·10	– 4·03	·70	– 8·59		
·02	– 2·00	·15	– 4·12	·75	– 8·68		
·04	– 2·04	·20	– 4·21	·80	– 8·76		
·06	– 2·07	·25	– 4·31	·85	– 8·84		
·08	– 2·11	·30	– 4·40	·90	– 8·93		
51·10	– 2·15	·35	– 4·49	·95	– 9·01		
·12	– 2·19	·40	– 4·58	55·00	– 9·09		
·14	– 2·23	·45	– 4·67	·05	– 9·18		
·16	– 2·26	52·50	– 4·76	·10	– 9·26		
·18	– 2·30	·55	– 4·85	·15	– 9·34		
51·20	– 2·34	·60	– 4·94	·20	– 9·42		
·22	– 2·38	·65	– 5·03	·25	– 9·51		

Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
90·00	+ 11·11	92·65	+ 7·93	95·30	+ 4·93	97·95	+ 2·09
·05	+ 11·05	·70	+ 7·87	·35	+ 4·87	98·00	+ 2·04
·10	+ 10·99	·75	+ 7·82	·40	+ 4·82	·05	+ 1·99
·15	+ 10·92	·80	+ 7·76	·45	+ 4·76	·10	+ 1·94
·20	+ 10·86	·85	+ 7·70	95·50	+ 4·71	·15	+ 1·88
·25	+ 10·80	·90	+ 7·64	·55	+ 4·65	·20	+ 1·83
·30	+ 10·74	·95	+ 7·59	·60	+ 4·60	·25	+ 1·78
·35	+ 10·68	93·00	+ 7·53	·65	+ 4·54	·30	+ 1·73
·40	+ 10·62	·05	+ 7·47	·70	+ 4·49	·35	+ 1·68
·45	+ 10·56	·10	+ 7·41	·75	+ 4·43	·40	+ 1·63
90·50	+ 10·50	·15	+ 7·36	·80	+ 4·38	·45	+ 1·57
·55	+ 10·44	·20	+ 7·30	·85	+ 4·33	98·50	+ 1·52
·60	+ 10·38	·25	+ 7·24	·90	+ 4·28	·55	+ 1·47
·65	+ 10·31	·30	+ 7·18	·95	+ 4·22	·60	+ 1·42
·70	+ 10·25	·35	+ 7·13	96·00	+ 4·17	·65	+ 1·37
·75	+ 10·19	·40	+ 7·07	·05	+ 4·11	·70	+ 1·32
·80	+ 10·13	·45	+ 7·01	·10	+ 4·06	·75	+ 1·26
·85	+ 10·07	93·50	+ 6·95	·15	+ 4·00	·80	+ 1·21
·90	+ 10·01	·55	+ 6·90	·20	+ 3·95	·85	+ 1·16
·95	+ 9·95	·60	+ 6·84	·25	+ 3·89	·90	+ 1·11
91·00	+ 9·89	·65	+ 6·78	·30	+ 3·84	·95	+ 1·06
·05	+ 9·83	·70	+ 6·72	·35	+ 3·78	99·00	+ 1·01
·10	+ 9·77	·75	+ 6·66	·40	+ 3·73	·05	+ 0·96
·15	+ 9·71	·80	+ 6·61	·45	+ 3·68	·10	+ 0·91
·20	+ 9·65	·85	+ 6·55	96·50	+ 3·63	·15	+ 0·86
·25	+ 9·59	·90	+ 6·50	·55	+ 3·57	·20	+ 0·81
·30	+ 9·53	·95	+ 6·44	·60	+ 3·52	·25	+ 0·75
·35	+ 9·47	94·00	+ 6·38	·65	+ 3·46	·30	+ 0·70
·40	+ 9·41	·05	+ 6·32	·70	+ 3·41	·35	+ 0·65
·45	+ 9·35	·10	+ 6·27	·75	+ 3·36	·40	+ 0·60
91·50	+ 9·29	·15	+ 6·21	·80	+ 3·31	·45	+ 0·55
·55	+ 9·23	·20	+ 6·16	·85	+ 3·25	99·50	+ 0·50
·60	+ 9·17	·25	+ 6·10	·90	+ 3·20	·55	+ 0·45
·65	+ 9·11	·30	+ 6·04	·95	+ 3·14	·60	+ 0·40
·70	+ 9·05	·35	+ 5·98	97·00	+ 3·09	·65	+ 0·35
·75	+ 8·99	·40	+ 5·93	·05	+ 3·04	·70	+ 0·30
·80	+ 8·93	·45	+ 5·87	·10	+ 2·99	·75	+ 0·25
·85	+ 8·87	94·50	+ 5·82	·15	+ 2·93	·80	+ 0·20
·90	+ 8·81	·55	+ 5·76	·20	+ 2·88	·85	+ 0·15
·95	+ 8·76	·60	+ 5·71	·25	+ 2·82	·90	+ 0·10
92·00	+ 8·70	·65	+ 5·65	·30	+ 2·77	·95	+ 0·05
·05	+ 8·64	·70	+ 5·60	·35	+ 2·72	100·00	Nil.
·10	+ 8·58	·75	+ 5·54	·40	+ 2·67	·05	− 0·05
·15	+ 8·52	·80	+ 5·49	·45	+ 2·61	·10	− 0·10
·20	+ 8·46	·85	+ 5·43	97·50	+ 2·56	·15	− 0·15
·25	+ 8·40	·90	+ 5·37	·55	+ 2·51	·20	− 0·20
·30	+ 8·34	·95	+ 5·31	·60	+ 2·46	·25	− 0·25
·35	+ 8·29	95·00	+ 5·26	·65	+ 2·40	·30	− 0·30
·40	+ 8·23	·05	+ 5·20	·70	+ 2·35	·35	− 0·35
·45	+ 8·17	·10	+ 5·15	·75	+ 2·30	·40	− 0·40
92·50	+ 8·11	·15	+ 5·09	·80	+ 2·25	·45	− 0·45
·55	+ 8·05	·20	+ 5·04	·85	+ 2·20	100·50	− 0·50
·60	+ 7·99	·25	+ 4·98	·90	+ 2·15	·55	− 0·55

Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.		Meter Registering 100 Feet.	
Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.	Reading of Scale of Gas-holder.	Amount of Error.
Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.	Feet.	Per Cent.
100·60	− 0·60	103·25	− 3·15	105·90	− 5·57	108·55	− 7·88
·65	− 0·65	·30	− 3·19	·95	− 5·62	·60	− 7·92
·70	− 0·70	·35	− 3·24	106·00	− 5·66	·65	− 7·96
·75	− 0·75	·40	− 3·29	·05	− 5·71	·70	− 8·00
·80	− 0·79	·45	− 3·34	·10	− 5·75	·75	− 8·05
·85	− 0·84	103·50	− 3·38	·15	− 5·80	·80	− 8·09
·90	− 0·89	·55	− 3·43	·20	− 5·84	·85	− 8·13
·95	− 0·94	·60	− 3·47	·25	− 5·88	·90	− 8·17
101·00	− 0·99	·65	− 3·52	·30	− 5·93	·95	− 8·22
·05	− 1·04	·70	− 3·57	·35	− 5·98	109·00	− 8·26
·10	− 1·09	·75	− 3·61	·40	− 6·02	·05	− 8·30
·15	− 1·14	·80	− 3·66	·45	− 6·06	·10	− 8·34
·20	− 1·19	·85	− 3·71	106·50	− 6·10	·15	− 8·38
·25	− 1·24	·90	− 3·75	·55	− 6·15	·20	− 8·42
·30	− 1·28	·95	− 3·80	·60	− 6·19	·25	− 8·47
·35	− 1·33	104·00	− 3·85	·65	− 6·24	·30	− 8·51
·40	− 1·38	·05	− 3·90	·70	− 6·28	·35	− 8·55
·45	− 1·43	·10	− 3·94	·75	− 6·33	·40	− 8·59
101·50	− 1·48	·15	− 3·99	·80	− 6·37	·45	− 8·64
·55	− 1·53	·20	− 4·03	·85	− 6·41	109·50	− 8·68
·60	− 1·57	·25	− 4·08	·90	− 6·45	·55	− 8·72
·65	− 1·62	·30	− 4·12	·95	− 6·50	·60	− 8·76
·70	− 1·67	·35	− 4·17	107·00	− 6·54	·65	− 8·80
·75	− 1·72	·40	− 4·21	·05	− 6·59	·70	− 8·84
·80	− 1·77	·45	− 4·26	·10	− 6·63	·75	− 8·89
·85	− 1·82	104·50	− 4·31	·15	− 6·68	·80	− 8·93
·90	− 1·87	·55	− 4·36	·20	− 6·72	·85	− 8·97
·95	− 1·91	·60	− 4·40	·25	− 6·76	·90	− 9·01
102·00	− 1·96	·65	− 4·45	·30	− 6·80	·95	− 9·05
·05	− 2·01	·70	− 4·49	·35	− 6·85	110·00	− 9·09
·10	− 2·06	·75	− 4·54	·40	− 6·89	·10	− 9·18
·15	− 2·10	·80	− 4·58	·45	− 6·94	·20	− 9·26
·20	− 2·15	·85	− 4·63	107·50	− 6·98	·30	− 9·34
·25	− 2·20	·90	− 4·67	·55	− 7·02	·40	− 9·42
·30	− 2·25	·95	− 4·72	·60	− 7·06	·50	− 9·51
·35	− 2·30	105·00	− 4·76	·65	− 7·11	·60	− 9·59
·40	− 2·34	·05	− 4·81	·70	− 7·15	·70	− 9·67
·45	− 2·39	·10	− 4·85	·75	− 7·20	·80	− 9·75
102·50	− 2·44	·15	− 4·90	·80	− 7·24	·90	− 9·83
·55	− 2·49	·20	− 4·94	·85	− 7·28	111·00	− 9·91
·60	− 2·53	·25	− 4·99	·90	− 7·32	·10	− 9·99
·65	− 2·58	·30	− 5·03	·95	− 7·37	·20	− 10·07
·70	− 2·63	·35	− 5·08	108·00	− 7·41	·30	− 10·15
·75	− 2·68	·40	− 5·12	·05	− 7·45	·40	− 10·23
·80	− 2·72	·45	− 5·17	·10	− 7·49	·50	− 10·31
·85	− 2·78	105·50	− 5·21	·15	− 7·54	·60	− 10·39
·90	− 2·82	·55	− 5·26	·20	− 7·58	·70	− 10·47
·95	− 2·87	·60	− 5·30	·25	− 7·62	·80	− 10·55
103·00	− 2·91	·65	− 5·35	·30	− 7·66	·90	− 10·63
·05	− 2·96	·70	− 5·39	·35	− 7·71	112·00	− 10·71
·10	− 3·01	·75	− 5·44	·40	− 7·75	·10	− 10·79
·15	− 3·06	·80	− 5·48	·45	− 7·79	·20	− 10·87
·20	− 3·10	·85	− 5·53	108·50	− 7·83	·30	− 10·95

NOTE.—Any other quantity may be calculated by the rule of proportion, thus:—

Meter registering	100·00 feet
Reading of scale of test gasholder. .	89·95 „
Difference	10·05 „

89·95 : 100 : : 10·05 : 11·17 fast.

And Meter registering	100·00 feet
Reading of scale of test gasholder. .	112·55 „
Difference	12·55 „

112·55 : 100 : : 12·55 : 11·15 slow.

TABLE

Showing the Dilatation of Gas in Contact with Water and Saturated with Aqueous Vapour, for given Temperature. (Professor Airey.)

(Used in making Corrections for Temperature in the Testing of Gas Meters.)

Temperature in Fahrenheit's Scale.	Percentage of Dilatation.	Temperature in Fahrenheit's Scale.	Percentage of Dilatation.	Temperature in Fahrenheit's Scale.	Percentage of Dilatation.
31·40	0	54·33	5½	74·30	11
33·54	½	56·24	6	75·94	11½
35·70	1	58·12	6½	77·23	12
37·84	1½	60·02	7	78·81	12½
39·91	2	62·00	7½	80·40	13
42·05	2½	63·77	8	81·94	13½
44·17	3	65·63	8½	83·44	14
46·22	3½	67·43	9	84·88	14½
48·25	4	69·18	9½	86·39	15
50·32	4½	70·90	10	87·88	15½
52·36	5	72·60	10½	89·20	16

NOTE.—The table shows the percentage of increase of the volume of gas above its volume at the temperature of 31·4° Fahr.

INTERNAL FITTINGS.

The advantages of an ample supply of good and pure gas are frequently neutralized by the defective manner in which premises are fitted internally.

Bad gas-fittings are generally the result of cupidity or ignorance. They are a common cause of complaint from consumers, who are often

ready to attribute the inefficient light which they afford to a want of pressure or purity, or a low illuminating power in the gas.

In the matter of internal fittings, the gas manager, by judgment and tact, can exercise a useful supervision even without the aid of statutory powers; and his advice in regard to the sizes of pipes, and the kind of burners and lamps to be used in different situations, will generally be accepted and acted upon.

The following regulations (with such additions and modifications as may be found necessary) may be adopted with advantage by gas Authorities.

Regulations as to Internal Fittings.

1. The Company's (or Local Authority's) servants will in all cases lay on the service-pipe, conveying the same through the outer wall of the premises to be supplied with gas.

2. The main-cock must be attached to the end of the service-pipe within the building, and close to the outer wall.

3. The gas meter must be placed perfectly level, either on the floor or on a substantial support, and within 2 ft. 6 in. of the main-cock.

4. The piping attached to the meter, whether inlet or outlet, must not be smaller in internal diameter than that of the meter unions.

5. The following are the sizes of the meters, and their measuring capacity, from which the number of lights which they supply can be readily calculated:—

Size of Meters.	Size of Inlet and Outlet. Inches.	Measuring Capacity per Revolution. Cubic Feet.	Measuring Capacity per Hour. Cubic Feet.
2-light	½	$\frac{1}{12}$	12
3 „	⅝	⅛	18
5 „	¾	¼	30
10 „	1	½	60
15 „	1	¾	90
20 „	1¼	1	120
30 „	1⅜	1½	180
50 „	1½	2½	300
60 „	1½	3	360
80 „	1¾	4	480
100 „	2	5	600
150 „	3	7½	900
200 „	3	10	1200
250 „	4	12½	1500
300 „	4	15	1800
400 „	4	20	2400
500 „	5	25	3000
600 „	5	30	3600

To ascertain the number of lights which any size of meter will supply, divide the measuring capacity per hour by the quantity of gas per hour which each jet is estimated to consume. Example: What number of lights, consuming 4 cubic feet of gas per hour, will a 20-light meter supply? Then, $\frac{120}{4} = 30$ lights.

6. The following are the sizes and lengths of iron, lead, or composition tubes to be used according to the number of ordinary lights:—

Internal Diameter of Tubing. Inches.	Greatest Length allowed. Feet.	Greatest No. of Burners allowed.
$\frac{3}{8}$	20	3
$\frac{1}{2}$	30	6
$\frac{5}{8}$	40	12
$\frac{3}{4}$	50	20
1	70	35
$1\frac{1}{4}$	100	60
$1\frac{1}{2}$	150	100
2	200	200

Tubing of $\frac{1}{4}$-inch bore is not allowed to be used.

7. The tubes or pipes must be laid with proper fall, and in such a manner that they are easily accessible, and protected from liability to damage. Attention is to be given to leaving a space round them at such places as wall crossings, &c., where fracture or crushing of the pipes might be caused by the subsidence of the building. The joinings of the tubes and pipes are to be made in the most solid and substantial manner; and carefully rounded bends (not elbows) are to be used wherever the direction of a pipe is changed.

8. Floor boards covering pipes must be secured with screws, so that they may be easily removed to afford access to the pipes, especially at the points of connection.

9. On the completion of the work of fitting, and before the piping is covered up, notice thereof must be given in writing to the gas manager (the requisite form for that purpose being obtained at the gas office), who will cause an inspection to be made of the work, and if found in accordance with the regulations herein contained, it will be passed by the Company (or Local Authority), and the gas turned on.

10. If the regulations are not conformed to in every respect, the Company (or Local Authority) reserve the right to refuse a supply of gas until the necessary alterations are made.

11. Gas-fitters complying with these regulations have their names

registered on the Company's (or Local Authority's) list of approved fitters, and they are at liberty to designate themselves "Authorized Gas-Fitters." Repeated negligence will cause the license to be withdrawn.

A handy and useful apparatus for testing the soundness of gas-fittings, has been devised by Harrison and Sheard. It consists of a small force pump and a King's pressure-gauge, in which mercury is employed instead of water; the two being connected together on one base board, and provided with a coupling for ready attachment to the fittings to be tested.

To use the apparatus, air is forced, by means of the pump, into the fittings until the pressure therein is equivalent to, say, 12 inches of water, as indicated on the dial of the gauge. The pump is then shut off by means of a stopcock, and it is noted whether the pressure is maintained or falls away. If the pointer remains stationary, the fittings are sound; while if it goes back, there is a leakage.

To facilitate the discovery of leakages, gas may be forced into the fittings, by connecting an inlet pipe on the pump, by means of india-rubber tubing, with any convenient gas supply; when the gas escaping through the defective fittings at a high pressure, enables the locality of the leakages to be readily discovered.

Ordinary sitting rooms are best lighted by means of a central chandelier. When the room is of large dimensions, wall brackets may be added. A bracket at each side of the mantelpiece has a tasteful appearance, and lights are handy in that position.

The jets of chandeliers and brackets should be not less than 36 inches from the ceiling.

A tea-spoonful of salad oil added on the top of the water in the tube of a water-slide pendant, tends, in a great measure, to prevent or retard evaporation of the water.

Burners arranged in the horizontal position are not usually effective, and are not to be recommended except on the conditions noted hereafter. The flames of such have an unpleasant pulsatory or tremulous motion, very disagreeable when fixed on a level with or but slightly above the eye of the spectator, due to the upward current of air striking the underside.

The arrangement is bad for another reason—viz., the flame is

prevented from receiving its due supply of oxygen on all sides, and as a consequence, the combustion is imperfect; bad illumination, and a deposit of unconsumed carbon on the ceiling being the result.

It is not, however, to be assumed that lights placed in the horizontal or the inclined position are never effective. They can be rendered so by causing the tails of the flames to impinge one upon the other, and by making provision in the construction of the pendant for the air current to play upon the upper surface of the flame.

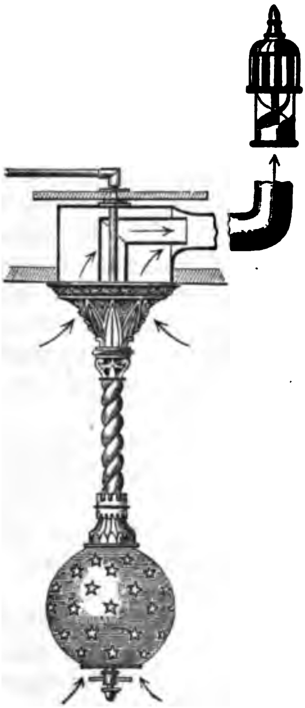


FIG. 141.

The question of the efficient ventilation of rooms where gas is being consumed is one of importance both to the gas producer and the user. The subject has been a comparatively neglected one, although it deserves to occupy greater prominence.

Ventilating globe and other lights of various designs have been introduced by Sugg, Cowan, Bray, Strode, Wenham (whose lamp is also regenerative), and other makers, with highly satisfactory results. Fig. 141 shows Cowan's ventilating globe light; and Fig. 142, the ventilating sunlight as made by Strode.

Gas burners are made with a precision unknown in the earlier days of gas lighting, and great improvements have been effected in their construction.

The old iron burner, which at one time was generally in use, robbing the flame of a proportion of its heat, has been supplanted by those made either wholly from steatite, lava, enamel, or other refractory non-conducting material, or tipped with these substances.

These are not only more efficient in action, but they are less subject to blocking, and they are more durable.

The burners made by Geo. Bray & Co. are so well known as to need no recommendation, their merits being universally recognized; but it is only fair that the important services which these makers have

rendered to the gas industry in this and other departments should be freely acknowledged.

Shades, moons, or globes, as they are variously named, have kept pace with the improvements in burners, being constructed not only of better and purer materials than formerly, but according to scientific principles.

At one time they were invariably made with the bottom openings about 2 inches in diameter; the effect being to direct the current of air upon the flame, lowering the temperature, impairing the illuminating effect, and causing an unpleasant flickering.

These have given place to globes with openings at least 4 inches in diameter, whereby the foregoing defects are entirely obviated, whilst the concave sides also act as reflectors of the light in the downward direction, especially below 45° from the horizontal. As Professor Lewes points out:* "In order to gain any true idea of illuminating effect, it is necessary to take the light emitted over all the working angles, and not on the horizontal plane."

FIG. 142.

Globes made of good and suitable materials, and untinted, diffuse the light without seriously obstructing it, even when the test is applied on the horizontal plane. This is particularly noticeable with the "holophane" globe recently introduced, and with the pure white opal globes.

For estimating (approximately) the number of burners required to light churches, public halls, and other large buildings, divide the floor area in feet by 60, and the quotient will be the number of flat-flame burners, consuming 16-candle gas, required for effective lighting.

Thus: A room is 80 ft. long and 56 ft. wide.

Then,— $80 \times 56 = 4480$ sq. ft. area, and

$\frac{4480}{60} = 74$ burners consuming 5 cubic feet of gas per hour each.

The Welsbach system of incandescent gas-lighting marks a notable advance in artificial illumination. The Welsbach lamp consists of a Bunsen burner, over which is suspended a mantle, composed of a

* Cantor Lecture, Society of Arts, delivered Nov. 30, 1896.

textile filament coated with certain rare refractory oxides. On lighting the burner, the textile portion is consumed, leaving the refractory portion in position, and this at once becomes incandescent, giving out a strong steady light. The fragility of the mantle was a hindrance to its early adoption, but this has proved to be less of a drawback than was at first anticipated, as is shown by the fact of the wide application of the system. The saving of gas that is effected by its use, the increase in illuminating effect, and the comparative coolness of the light, with other advantages, have earned for it a deserved reputation.

To obtain the maximum of light from a burner, the pressure, when that is in excess in the mains, as it must necessarily be, should be controlled and regulated in the passage of the gas to the point of ignition.

This cannot be accomplished satisfactorily by checking either the taps on the fittings, or the stopcock at the meter, because there is a continual variation of pressure according to the consumption that is in progress.

The house governor or regulator was invented to achieve that end. It may be fixed on the pipe leading from the meter outlet, or what is better, on the principal pipe supplying each floor level of the premises.

The regulator is automatic in its action; and when weighted to afford the required pressure for all the burners in use, it will continue to give a practically uniform supply, however much the pressure in the mains may vary, or whether the whole or only a portion of the burners being supplied through it may be alight at one time. Sugg's regulator burner, Peebles's "Needle" governor burner, and the "Acme" regulating burner of Wright, are examples of regulation applied close to the point of consumption.

It is a clearly established fact that the lower the pressure (provided there is just sufficient) at which gas can be burned, the better the light. If, instead of being advantageously consumed, the gas is forced through the burners into the atmosphere, the carbon is rapidly oxidized by the excess of air drawn into the flame by the heavy pressure, with the usual unsatisfactory results as regards illumination.

Dr. Letheby found that a vulcanized india-rubber tube of about 30 ft. in length, reduced the power of a weak gas to the extent of nearly 25 per cent., by absorbing the illuminating hydrocarbons.

Varnish to Prevent the Escape of Gas through India-Rubber Tubing.

1½ parts treacle.
2 ,, gum arabic.
7 ,, white wine.
8½ ,, strong alcohol.

First dissolve the treacle and gum in the white wine, and afterwards add the alcohol very slowly, constantly stirring the mixture to prevent the gum from being thrown down.

LEAD AND COMPOSITION PIPES FOR GAS.

Weights per Yard, and Lengths usually Manufactured.

Light.			Heavy.		
Diameter Inside.	Weight per Yard. lbs. oz.	Lengths of Bundles usually Manufactured.	Diameter Inside.	Weight per Yard. lbs. oz.	Lengths of Bundles usually Manufactured.
¼ inch.	0 11½	80 yards.	¼ inch.	0 15	67 yards.
⅜ ,,	1 2	60 ,,	⅜ ,,	1 6½	46 ,,
½ ,,	2 0	32 ,,	½ ,,	2 10	16 ,,
⅝ ,,	2 4	25 ,,	⅝ ,,	3 0	20 ,,
¾ ,,	3 8	28 ,,	¾ ,,	3 12	19 ,,
1 ,,	4 8	26 ,,	1 ,,	6 0	20 ,,
1¼ ,,	8 0	16 ,,	1¼ ,,	10 0	12 ,,
1½ ,,	12 0	10 ,,	1½ ,,	14 0	9 ,,
2 ,,	18 0	5 ,,	2 ,,	21 0	5 ,,

BRASS TUBE, PLAIN—WEIGHT PER FOOT.

Diameter. Inches.	Weight. lbs.	oz.	Diameter. Inches.	Weight. lbs.	oz.
1-4th	·08 or	1·28	7-8ths	·50 or	8·00
5-16ths	·15	2·40	1 inch	·59	9·44
3-8ths	·19	3·04	1¼ ,,	·81	12·96
7-16ths	·21	3·36	1½ ,,	1·00	16·00
1-half	·25	4·00	1¾ ,,	1·12	17·92
9-16ths	·31	4·96	2 ,,	1·25	20·00
5-8ths	·37	5·92	2½ ,,	1·50	24·00
3-4ths	·43	6·88	3 ,,	1·87	29·92

The size of brass and copper tube is measured by the outside diameter.

BRASS TUBE, SPIRAL AND FLUTED—WEIGHT PER FOOT.

Diameter. Inches.	Spiral, Weight. oz.	Fluted, Weight. oz.	Diameter. Inches.	Spiral, Weight. oz.	Fluted, Weight. oz.
3-8ths	3	2¾	3-4ths	6	6
7-16ths	3½	3½	7-8ths	7¼	7
1-half	3¾	3½	1 inch	9	8
9-16ths	4½	4	1¼ ,,	12	11
5-8ths	5	5	1½ ,,	15	14

SOLDERS.

Fine Solder is an alloy of 2 parts of block tin and 1 of lead (melts at 360° Fahr.). This is used for fine work—such as soldering the drums of meters, for pewter, &c.

Glazing Solder.—Equal parts of block tin and lead. Used for lead.

Plumbing Solder.—1 part block tin, 2 lead. For all kinds of plumbers' joints and for tin and zinc.

Solder for Copper.—Hard: 3 parts brass, 1 zinc. Soft: 8 brass, 1 zinc.

Brazing Solder or Spelter.—Hard: 1 part copper, 1 zinc. Soft: 4 parts copper, 3 zinc, 1 block tin. For fine brass work: 1 part silver, 8 copper, 8 zinc.

Solder for Steel.—19 parts silver, 3 copper, 1 zinc.

Pewterers' Soft Solder.—2 parts bismuth, 4 lead, 3 tin. Common: 1 part bismuth, 1 lead, 2 tin.

FLUXES FOR SOLDERING.

Iron and steel	Borax or sal ammoniac.
Tinned iron	Resin or chloride of zinc.
Copper and brass	Sal ammoniac or chloride of zinc.
Lead and composition pipes	Resin and sweet oil.
Zinc	Chloride of zinc.

FOR TINNING BRASS OR IRON.

½ oz. muriatic acid.
¼ oz. mercury.
½ oz. ground block tin.

Mix together, and dilute the whole with a small quantity of cold water. Apply with the finger or a cork.

BRAZING.

The edges of the articles, either iron or brass, to be brazed are scraped thoroughly clean, covered with the brazing solder or spelter in the form of borings or turnings sprinkled over with powdered borax, and exposed to the heat of a clear fire till the solder flows. A smokeless coke or gas fire is best for the purpose. In brazing iron, a covering of loam is sometimes placed over the solder, to exclude the air, till it melts.

BRONZE.

1 quart common vinegar.
2 ozs. sal ammoniac.
1 oz. blue stone (sulphate of copper).

The sal ammoniac and blue stone are well pounded, and then allowed to dissolve in the vinegar. The solution, when ready, is laid on with a common brush, black-leaded whilst damp, and then polished. Lacquer is then applied as described hereafter.

Green Bronze.

To imitate the antique.
1 quart common vinegar.
2 ozs. verdigris.
1 oz. sal ammoniac.

Boil for a quarter of an hour, filter through paper, and dilute with water. Immerse the article to be bronzed until it acquires the green tinge desired; then wash carefully, and dry in sawdust.

Bronze Powders.

These can be purchased from any dealer in artists' material. They are prepared as follows :—

Copper Bronze Powder.

Strips of copper are dissolved in nitric acid in a glass vessel, and then strips of iron are added, when the dissolved copper is precipitated in the form of a very fine powder. This powder is washed with water and dried, and is then ready for use.

Gold Bronze Powder, or Aurum Mosaicum,

Is the basis of many bronze powders. Any desired colour can be produced by mixing it with the common dry pigments. Thus a red bronze powder is obtained by grinding red lead with it; and a green by the use of verdigris. It is prepared in the following manner :—

One pound of tin is melted in a crucible, and then poured cautiously into an iron dish containing half a pound of mercury. When cold it is reduced to powder, mixed with seven ounces of flowers of sulphur, and eight ounces of sal ammoniac, and triturated in a mortar. The mixture is then calcined in a flask, which expels the sulphur, mercury, and ammonia, and leaves a residuum in the form and colour of a bright flaky gold powder.

Size for Bronze Powders.

The size is made by boiling four ounces of gum animi to every pound of pure linseed oil in a flask, until the mixture is of the consistency of cream; after which it is diluted with turpentine as required.

The article to be bronzed is coated, by means of a soft brush, with this size; and when nearly dry, a piece of soft leather is wrapped round the finger, dipped into the powder, and rubbed gently over it; or it may be laid on with a camel's-hair pencil, and then left to dry thoroughly; after which all the loose powder is brushed off.

The bronze may also be mixed with a strong solution of isinglass, and applied in the moist state, like varnish, with a brush. This latter mode, however, is not suitable for articles exposed to the weather.

For Silvering Metals.

Nitrate of silver	10	parts.
Common salt	10	,,
Cream of tartar	30	,,

Moisten with water when ready to apply, and lay the mixture on with a soft brush.

LACQUER AND VARNISH.

The solution of spirits of wine and shellac, known as "simple pale" lacquer, is the basis of most other lacquers. The two ingredients in their proper proportions, as stated overleaf, are put into a jar or bottle, and allowed to remain for forty-eight hours, being briskly shaken three or four times during the interval. At the expiration of the time named, most of the shellac will be dissolved. The mixture is then carefully strained through filtering paper, to free it from grit and other foreign substances, and to remove any particles of undissolved shellac that may remain.

Different tints or shades, producing red, green, yellow, &c., are obtained by mixing with the pale lacquer various colouring ingredients, such as dragon's blood, arnotto, gamboge, turmeric, saffron, &c. The proper way of adding these is to stir them in a cup with a small quantity of the pale lacquer, afterwards straining the whole through a piece of thin cloth or gauze, and filtering if necessary.

The article to be lacquered is heated slightly by means of a steam

kettle or stove; or it may be held over a hot iron plate till just as hot as to allow of its being touched by the finger without burning. The heat must not be greater than this. The lacquer is then applied with a soft camel's-hair brush.

Simple Pale Lacquer.

1 pint of spirits of wine.
4 ozs. of shellac.

Fine Pale Lacquer.

1 pint of spirits of wine.
1 oz. of pure white shellac.
1 dr. of gamboge.
2 drs. of Cape aloes.

Fine Pale Lacquer, for Silvered or Tinned Work.

1 pint of spirits of wine.
1 oz. of pure white shellac.

Gold Lacquer.

1 pint of spirits of wine.
8 ozs. of shellac.
½ oz. turmeric.
2 drs. of arnotto.
2 drs. of saffron.

Deep Gold Lacquer.

1 pint of spirits of wine.
8 ozs. of shellac.
½ oz. of turmeric.
4 drs. of dragon's blood.

Red Lacquer.

1 pint of spirits of wine.
4 ozs. of shellac.
4 drs. of dragon's blood.
1 dr. of gamboge.

Yellow Lacquer.

1 pint of spirits of wine.
2 ozs. of shellac.
2 drs. of gamboge.
4 drs. of Cape aloes.

Green Lacquer for Bronze.

1 pint of spirits of wine.
4 ozs. of shellac.
4 drs. of turmeric.
½ dr. of gamboge.

Iron Lacquer.

1 quart of turpentine.
¾ lb. of pitch.
2 ozs. of shellac.

To Clean Old Brass Work for Lacquering.

Boil a strong lye of wood ashes, and strengthen with soap lees; put in the brass work, and the old lacquer will come off. Next dip it in a solution of nitric acid and water strong enough to remove the dirt; wash it immediately in clean water; dry well, and lacquer.

Varnish for Iron Work.

Boil a quantity of gas tar for four or five hours, till it runs as thin as water; add one quart of turpentine to a gallon of the tar, and boil another half hour. Apply the varnish whilst hot.

Golden Varnish.

Pulverize 1 drachm of saffron and ½ a drachm of dragon's blood, and put them into 1 pint of spirits of wine. Add 2 ounces of gum shellac and 2 drachms of Soccotrine aloes. Dissolve the whole by gentle heat. Yellow painted work, varnished with this mixture, will appear almost equal to gold.

Glue Cement to Resist Moisture.

1 part glue.
1 part black resin.
¼ part red ochre.

Mix with the least possible quantity of water.

COAL GAS TESTING APPLIANCES AND METHODS.

A gas may have a high illuminating power, and yet contain impurities that ought to be removed. Purity is not always in the ratio of illuminating power.

TESTS FOR IMPURITIES.

The tests for the detection of impurities in coal gas, after it has undergone the different processes of purification, are the following :—

Test for Ammonia.—Expose yellow turmeric paper slightly moistened with water, or litmus paper first reddened by any weak acid, to a jet of unlighted gas for about a minute. If the yellow colour of the turmeric be turned to brown, or if the blue of the litmus be restored, ammonia is present.

Turmeric and litmus papers may be purchased at the chemist's, or they can be prepared as follows:

> ***Turmeric Paper.***—Six parts by weight of spirits of wine are added to one of turmeric powder in a stoppered bottle, and well shaken up occasionally for three days. A portion of the clear fluid is then poured on a plate, and pieces of unsized white filtering paper well soaked therein. These are then dried in air, cut into strips half an inch wide and two inches long, and kept for use in a bottle away from the light.
>
> ***Litmus Paper.***—Six parts by weight of water to one of powdered litmus, shaken well together, allowed to stand for several days, and then filtered. Pieces of white filtering paper are then thoroughly soaked in the solution, dried, and cut into strips, which should be kept in a close stoppered bottle, excluded as much as possible from the air and light. Should it be desired to redden the solution, add (after filtration) a small quantity of very dilute sulphuric acid, gradually, drop by drop, until the pink or neutral tinge is obtained.

Test for Carbonic Acid.—Make a solution of pure barytes, and pass the gas through it. If carbonic acid be present, carbonate of barytes will be precipitated; or pass the gas through clear lime water, and carbonate of lime will be precipitated.

It may also be detected by adding to water impregnated with the gas a few drops of sulphuric acid, when minute bubbles of carbonic acid gas will be rapidly disengaged.

Lime Water is prepared by agitating slaked lime with distilled water in a bottle or other vessel. It is then allowed to stand until the excess of lime has been deposited, when the clear liquid is poured off, and filtered through filtering paper.

Test for Sulphuretted Hydrogen.—Moisten a piece of writing-paper with a solution of acetate of lead in distilled water, and expose it for not less than a minute to a jet of unlighted gas. If sulphuretted hydrogen be present, the paper will be browned or blackened.

A solution of nitrate of silver is a more delicate test than the above. This requires to be kept in a bottle coated outside with tinfoil, and placed in a drawer or other dark place to protect it from the influence of the light.

Lead paper may be made of white filtering paper soaked in the acetate of lead solution, then dried, cut into slips, and kept in a well-corked bottle for use. But the solution applied to the paper at the time of making the test is preferable.

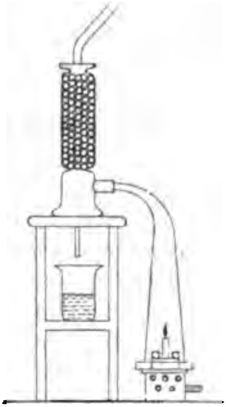
The Gas-Works Clauses Act, 1871, Schedule A, contains the following regulations in respect of the apparatus and mode of testing for this impurity:—

Apparatus.—"A glass vessel (Fig. 143) containing a strip of bibulous paper moistened with a solution of acetate of lead, containing 60 grains of crystalized acetate of lead dissolved in one fluid ounce of water.

Mode of Testing.—"The gas shall be passed through the glass vessel containing the strip of bibulous paper moistened with the solution of the acetate of lead for a period of three minutes, or such longer period as may be prescribed; and if any discoloration of the test paper is found to have taken place, this is to be held conclusive as to the presence of sulphuretted hydrogen in the gas."


FIG. 143.

Test for Sulphur.—The sulphur present in gas, due to compounds other than sulphuretted hydrogen, notably bisulphide of carbon, is estimated by burning a jet of the gas at the rate of one cubic foot, or



half a cubic foot, per hour, for 24 hours, from a Leslie or other burner arranged within the wide end of a trumpet tube whose upper and smaller end is inserted in a condenser, from the opposite end of which a tube carries off the uncondensed vapour, and creates a current through the apparatus. (See Fig. 144.) Through the lower and wide end, where the burner is fixed, a supply of air, to support combustion, enters, carrying with it the vapour of ammonia from liquid ammonia or pieces of the carbonate contained in a suitable receptacle surrounding the burner. The ammonia combining with the sulphurous acid from the gas-flame, is deposited within the condenser as sulphite and sulphate of ammonia, from which the quantity of sulphur per 100 cubic feet of gas is calculated.

FIG. 144.

Mr. J. T. Sheard's method of estimating carbonic acid in coal gas consists in passing a definite volume of gas through a solution of

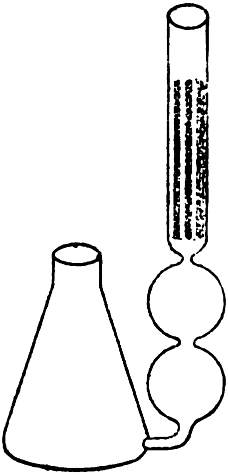


FIG. 145.

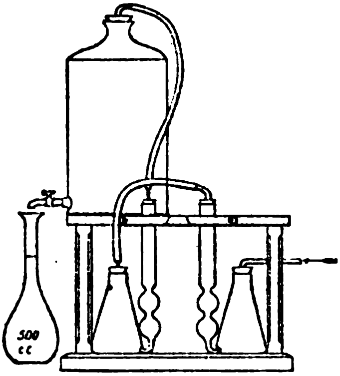


FIG. 145A.

barium hydrate of known strength, which absorbs the carbonic acid out of the gas; the amount of free hydrate remaining after the operation being determined by titration with deci-normal hydrochloric

acid. Either the volume or the weight of impurity that has been absorbed can thence be calculated.

The gas absorption tube is of the form shown in Fig. 145; the straight part above the bulbs being filled with glass beads.

To make a test, two absorption tubes are charged with 20 or 80 cubic centimetres each, of a barium hydrate solution, the strength of which has been accurately determined by titration with deci-normal acid, and which should be approximately of equal strength, with the acid. The apparatus being connected up as shown, Fig. 145A, 500 c.c. of gas are drawn by means of the aspirator slowly through the liquid, and followed immediately, without stopping the current, by an equal quantity of air, which is done by slipping off the india-rubber tube at the inlet of the apparatus, as the water running from the aspirator passes the mark of a 500 c.c. flask, and then running out a further quantity of 500 c.c. into another flask held in readiness. The bulbs are then washed down with water free from carbonic acid, a few drops of the phenol-phthalein (sufficient to impart a distinct purple red colour to the liquid) added, and the whole titrated with deci-normal hydrochloric acid—the acid being added a few drops at a time, with frequent agitation of the liquid until the colour is destroyed. The amount of barium hydrate that has been neutralized is equivalent to the amount of carbonic acid absorbed from 500 c.c. of gas; from which the percentage of the impurity present, or its weight per cubic foot of gas, can be determined.

EXAMPLE.—Two gas absorption tubes charged, respectively, with 80 c.c. and 20 c.c. of barium hydrate solution. One cubic centimetre of the barium hydrate having previously been found by experiment as equivalent to 1·09 of $\frac{N}{10}$ acid.

	First Tube.		Second Tube.
Equivalent of barium hydrate employed . .	82·7 c.c.	..	21·8 c.c.
$\frac{N}{10}$ acid required to neutralize resultant liquid.	21·6 c.c.	..	21·4 c.c.
	11·1 c.c.		0·4 c.c.

Then,—

$$\frac{11 \cdot 5 \text{ c.c.} \times 0 \cdot 0022 \text{ grm.} \times 100}{0 \cdot 914 \text{ grm.}} = 2 \cdot 77 \text{ per cent. by volume of } CO_2$$

$$\frac{11 \cdot 5 \text{ c.c.} \times 0 \cdot 0022 \text{ grm.} \times 15 \cdot 432 \text{ grs.} \times 28{,}315 \text{ c.c.}}{500 \text{ c.c.}} = 22 \cdot 1$$

grains of CO_2 per cubic foot of gas.*

These calculations may be shortened by employing the factor 0·241 for percentage by volume, and 1·92 for grains per cubic foot. Thus—

$$11 \cdot 5 \times 0 \cdot 241 = 2 \cdot 77 \text{ per cent. by volume of } CO_2$$
$$11 \cdot 5 \times 1 \cdot 92 = 22 \cdot 1 \text{ grains of } CO_2 \text{ per cub. ft. of gas.}$$

A complete test can be made in fifteen minutes, and perfectly accurate results obtained.

The apparatus is equally applicable to the estimation of ammonia and sulphuretted hydrogen in the gas, the former being absorbed by sulphuric acid of deci-normal strength and the latter by a 10 per cent. solution of sulphate of copper. When sulphuretted hydrogen is passed into an aqueous solution of cupric sulphate, a precipitate of cupric sulphide is deposited and free sulphuric acid is formed in the solution, previously neutral. After filtering out the precipitate, the acidity of the solution can be determined by titration with deci-normal ammonia, using methyl orange as indicator. Each cubic centimetre of $\frac{N}{10}$ ammonia required to neutralize the solution represents 1·48 grains of sulphuretted hydrogen per cubic foot of gas. Likewise each c.c. of $\frac{N}{10}$ acid neutralized by the ammonia in the gas represents 1·48 grains of ammonia per cubic foot of gas.

The manipulation of the apparatus is the same as above described for carbonic acid, and all three impurities may be determined in the same sample of gas. For this purpose one absorption tube is charged with acid for absorbing ammonia, followed by one containing cupric sulphate for sulphuretted hydrogen, and this by the tubes containing barium hydrate for carbonic acid. 500 c.c. of gas are drawn through

* It may be explained that—

0·0022 grm. is the weight of CO_2 to which 1 c.c. of $\frac{N}{10}$ acid is equivalent.
0·914 grm. is the weight of 500 c.c. of CO_2 saturated with moisture.
15·432 grs. is the value of 1 gramme.
28,315 c.c. is the value of 1 cubic foot.

the whole series, followed by 1,000 c.c. of air to clear the apparatus. The subsequent treatment will be understood from what has gone before.

Harcourt's Colour Test.—This is one of the most useful apparatus in the gas manager's laboratory for determining with ease and celerity the amount of bisulphide of carbon, sulphuretted hydrogen, and carbonic acid in coal gas. The following is a description of the test, and directions for its use.

Testing for Bisulphide of Carbon.—The arrangement of the colour test is shown in Fig. 146; the fire-clay cylinder being represented

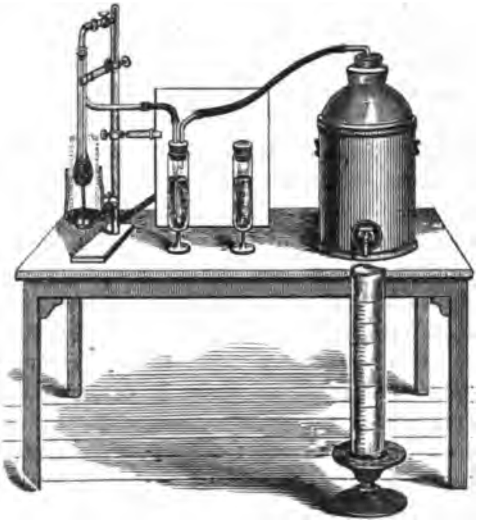


FIG. 146.

by dotted lines. The bulb, which is filled with platinized pumice, is to be so adjusted that it may be about an inch above the burner, and in the middle of the cylinder.

To use the apparatus, turn on first the upper stopcock, sending gas through the bulb at the rate of about half a cubic foot an hour, as may be judged by lighting the gas for a moment at the end of the horizontal arm, when a flame about an inch in length should be produced. Raise the cylinder, which will be supported by the pressure of the wires, light the burner, and turn down the flame till it forms a blue

non-luminous ring. Lower the cylinder, and place the small clay pieces upon it round the neck of the bulb.

A testing may be made five minutes after the burner is lighted, except when the apparatus is first used, when the gas should be allowed to flow through the bulb for a quarter of an hour, or a little longer, and any number of testings one after another as long as the heat is continued.

The mode of testing is as follows:—Lay a piece of white paper on the table by the side of the burner, and fix a piece of cardboard upright in the brass clip; the cardboard serves as a background against which to observe the colour of the contents of the glasses, and should receive a side light, and be as clear as possible from shadows. Fill one glass (once for all) up to the mark with standard coloured liquid, and cork it tightly. Dilute some of the lead syrup with twenty times its volume of distilled water, and fill the other glass up to the mark with a portion of the liquid thus prepared. Insert the caoutchouc plug with capillary-tube and elbow-tube, and connect, as shown in the figure, with the bulb and aspirator, placing the two glasses side by side.

The aspirator should be full of water at starting, and the measuring cylinder empty. Turn the tap of the aspirator gradually; a stream of bubbles will rise through the solution of lead. Turn off the tap for a minute, and observe the liquid at the bottom of the capillary-tube. If it gradually rises, the india-rubber connections are not air-tight, and must be made so before proceeding. Avoid pressing the plugs into the glass or the aspirator while they are connected, which would drive up the lead solution into the inlet-tube. When the connections are air-tight, let the water run into the measuring cylinder in a slender stream until the lead solution has become as dark as the standard. As the ascending bubbles interfere somewhat with the observation of the tint, it is best to turn off the tap when the colour seems almost deep enough; compare the two; turn on the tap, if necessary, for a few moments, then compare again; and so on, till the colour of the two liquids is the same.

The volume of water which the measuring cylinder now contains is equal to the volume of gas which has passed through the lead solution.

This volume of gas contained a quantity of sulphur as carbon bisulphide which, as lead sulphide, has coloured the liquid in the test-

glass up to the standard tint. The standard has been made such that, to impart this tint to the volume of liquid, 0·0187 grain of lead sulphide must be present, containing 0·0025 grain of sulphur. Hence, supposing the measuring cylinder, each division of which corresponds to 1-2000th cubic foot, to have been filled to the 30th division, 30-2000ths cubic foot of gas contained 0·0025 grain of sulphur. From this ratio the number of grains of sulphur existing as bisulphide in 100 cubic feet of the sample of gas tested can easily be calculated.

The following table gives the relation between (V) the divisions of the measuring cylinder filled with water, and (S) the grains of sulphur existing as bisulphide in 100 cubic feet of gas. Since gas contains besides carbon bisulphide, some other sulphur compounds which are not transformed into sulphuretted hydrogen by the action of heat, and which contain sulphur amounting ordinarily to 7 or 8 grains in 100 cubic feet, this quantity must be added to that found by the test, if it is wished to know approximately the total amount of sulphur.

TABLE I.

$$S = \frac{500}{V}$$

V	S	V	S	V	S	V	S
10	50·0	33	15·1	56	8·9	79	6·3
11	45·4	34	14·7	57	8·8	80	6·2
12	41·7	35	14·3	58	8·6	81	6·2
13	38·5	36	13·9	59	8·5	82	6·1
14	35·7	37	13·5	60	8·3	83	6·0
15	33·3	38	13·2	61	8·2	84	6·0
16	31·3	39	12·8	62	8·1	85	5·9
17	29·4	40	12·5	63	7·9	86	5·8
18	27·8	41	12·2	64	7·8	87	5·7
19	26·3	42	11·9	65	7·7	88	5·7
20	25·0	43	11·6	66	7·6	89	5·6
21	23·8	44	11·4	67	7·5	90	5·6
22	22·7	45	11·1	68	7·4	91	5·5
23	21·7	46	10·9	69	7·2	92	5·4
24	20·8	47	10·6	70	7·1	93	5·4
25	20·0	48	10·4	71	7·0	94	5·3
26	19·2	49	10·2	72	6·9	95	5·3
27	18·5	50	10·0	73	6·9	96	5·2
28	17·9	51	9·8	74	6·8	97	5·2
29	17·2	52	9·6	75	6·7	98	5·1
30	16·7	53	9·4	76	6·6	99	5·1
31	16·1	54	9·2	77	6·5	100	5·0
32	15·6	55	9·1	78	6·4	150	3·3

For the next testing, the test-glass is to be disconnected and re-charged. The water in the measuring cylinders is poured back into the aspirator.

The colour of the standard is unaffected by exposure to light, but deepens if the liquid is warmed, returning to its original shade as the liquid cools. If, therefore, the glass containing the standard has been in a warm place, it must be let cool before testing.

The liquid which has been used becomes colourless after being exposed to the light for a few hours, and may thus be used over and over again for 20 times or more, if it is not allowed to absorb carbonic acid from the air. The best mode of working is to have two well-corked flasks, into one of which the coloured liquid is emptied while the glass is re-charged from the other.

Testing for Sulphuretted Hydrogen and Carbonic Acid.—The apparatus may also be used without the bulb-tube and stand to test the amount of sulphuretted hydrogen or carbonic acid in gas at any stage in its purification.

The gas is led in this case directly into the test-glass, which is charged with lead solution for sulphuretted hydrogen, and with a saturated solution of barium hydrate (baryta water) for carbonic acid.

When the gas contains more than 50 grains of sulphur as sulphuretted hydrogen in 100 cubic feet, a smaller cylinder, containing 1-200th cubic foot, is used to measure the volume of liquid run from the aspirator. The divisions on the smaller cylinder are tenths of the corresponding divisions on the larger cylinder; therefore when it is used the numbers under S in Table I. must be read as whole numbers by omitting the decimal points.

To estimate carbonic acid a standard liquid containing a definite amount of suspended barium carbonate is used for comparison. The glasses are placed side by side on a blackened board or piece of paper and with a black background behind them. The passage of the gas should be interrupted, and the test-glass slightly shaken once or twice to wash down any particles of carbonate which may cling to the sides of the glass above the surface of the liquid. The standard should also be shaken before the comparison is made, in order that the precipitates may be in a similar condition. When the two liquids are judged to be equally white and opaque, the volume of water in the measuring cylinder gives the volume of gas which has precipitated a known weight of barium carbonate. Table II. gives the relation between (V) the divisions of the large measuring cylinder filled with water, and (C) the volume of carbonic acid in 100 volumes of gas. When

the gas contains more than ·72 per cent. of carbonic acid, the smaller measuring cylinder should be used, and the values of (C) multiplied by moving the decimal point one place to the right.

TABLE II.

V	C	V	C	V	C	V	C
10	·72	33	·22	56	·13	79	·09
11	·65	34	·21	57	·13	80	·09
12	·60	35	·21	58	·12	81	·09
13	·55	36	·20	59	·12	82	·09
14	·51	37	·20	60	·12	83	·09
15	·48	38	·19	61	·12	84	·09
16	·45	39	·18	62	·11	85	·08
17	·42	40	·18	63	·11	86	·08
18	·40	41	·17	64	·11	87	·08
19	·38	42	·17	65	·11	88	·08
20	·36	43	·17	66	·11	89	·08
21	·34	44	·16	67	·11	90	·08
22	·33	45	·16	68	·11	91	·08
23	·31	46	·16	69	·10	92	·08
24	·30	47	·15	70	·10	93	·08
25	·29	48	·15	71	·10	94	·08
26	·28	49	·15	72	·10	95	·08
27	·27	50	·14	73	·10	96	07
28	·26	51	·14	74	·10	97	·07
29	·25	52	·14	75	·10	98	·07
30	·24	53	·14	76	·09	99	·07
31	·23	54	·13	77	·09	100	·07
32	·22	55	·13	78	·09	150	·05

After each testing the glass and capillary-tube should be cleaned with a little dilute hydrochloric acid and well rinsed with distilled water. The turbid liquid is poured into a flask, which should be kept well corked, containing an excess of crystallized barium hydrate. After the suspended precipitate has subsided, the clear liquid is poured off, or, if necessary, filtered, into another flask, also kept well corked, from which it may be poured into the test-glass when required. Care should be taken not to expose the solution to the air longer than necessary.

Notification of the London Gas Referees.—These instructions as to the times and mode of testing for purity and illuminating power are applicable, primarily, to the Metropolis; but, secondarily, they will be found useful by every gas manager, the description of the *modus operandi* of testings, as well as of the appliances, being full and precise. They are as follows:—

Times and Mode of Testing for Purity.—"The testings for purity shall extend over not less than fifteen hours of each day, and shall be made upon ten cubic feet of gas. The gas shall be tested

successively for sulphuretted hydrogen, ammonia, and sulphur compounds other than sulphuretted hydrogen in the manner hereinafter prescribed. These testings must be started between 9 a.m. and 5.30 p.m., and must be concluded before 9 a.m. on the following morning. They are concluded by the action of an automatic lever-tap attached to the meter, which stops the passage of the gas when ten cubic feet have passed. A clock connected with the lever-tap is stopped at the same moment, leaving a record of the time; and the tap of an ærorthometer is turned, leaving a record of the final conditions under which the gas was measured by the meter.

"The liquids in the sulphur and ammonia tests, and the slips of paper in the tests for sulphuretted hydrogen then contain the sulphur and ammonia which were present in the gas supplied to the testing place during the day which ended at 9 a.m. The chemical examination of these liquids may be made on the following day, that is to say, after 9 a.m.

I. ***Sulphuretted Hydrogen.***—"The gas shall be passed as it leaves the service-pipe through a small governor and thence through an apparatus (Fig. 147) in which are suspended slips of bibulous paper, impregnated with basic acetate of lead.

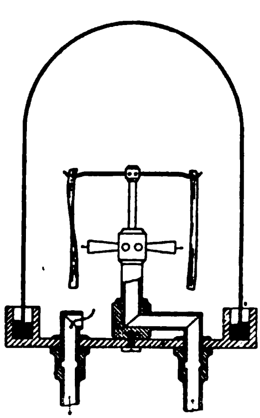


Fig. 147.

"The test-paper from which these slips are cut is to be prepared from time to time by moistening sheets of bibulous paper with a solution of one part of sugar of lead in eight or nine parts of water, and holding each sheet while still damp over the surface of a strong solution of ammonia for a few moments. As the paper dries all free ammonia escapes.

"If distinct discoloration of the surface of the test-paper is found to have taken place, this is to be held conclusive as to the presence of sulphuretted hydrogen in the gas. Fresh test-slips are to be placed in the apparatus every day.

"In the event of any impurity being discovered, one of the test slips shall be placed in a stoppered bottle and kept in the dark at the testing-place; the remaining slips shall be forwarded with the daily report.

II. *Ammonia.*—" The gas which has been tested for sulphuretted hydrogen shall pass next through an apparatus consisting of a glass cylinder filled with glass beads, which have been moistened with a measured quantity of standard sulphuric acid. A set of burettes, properly graduated, is provided.

" The maximum amount of ammonia allowed is 4 grains per 100 cubic feet of gas; and the examination of the liquid shall be made so as to show the exact amount of ammonia in the gas.

" Two test-solutions are to be used—one consisting of dilute sulphuric acid of such strength that 25 measures (septems) will neutralize 1 grain of ammonia; the other a weak solution of ammonia, 100 measures of which contain 1 grain of ammonia.

" The correctness of the result to be obtained depends upon the fulfilment of two conditions :—

1. " The preparation of test-solutions having the proper strength.
2. " The accurate performance of the operation of testing.

" To prepare the test-solutions the following processes may be used by the Gas Examiner :—

" Measure a gallon of distilled water into a clean earthenware jar, or other suitable vessel. Add to this 94 septems of pure concentrated sulphuric acid, and mix thoroughly. Take exactly 50 septems of the liquid and precipitate it with barium chloride in the manner prescribed for the sulphur test. The weight of barium sulphate which 50 septems of the test-acid should yield is 13·8 grains. The weight obtained with the dilute acid prepared as above will be somewhat greater, unless the sulphuric acid used had a specific gravity below 1·84.

" Add now to the diluted acid a measured quantity of water, which is to be found by subtracting 13·8 from the weight of barium sulphate obtained in the experiment, and multiplying the difference by 726. The resulting number is the number of septems of water to be added.

" If these operations have been accurately performed, a second precipitation and weighing of the barium sulphate obtainable from 50 septems of the test-acid will give nearly the correct number of 13·8 grains. If the weight exceeds 13·9 grains, or falls below 13·7 grains, more water or sulphuric acid must be added, and fresh trials made, until the weight falls within these limits. The test-acid thus prepared should be transferred at once to stoppered bottles, which have been well drained and are duly labelled.

"To prepare the standard solution of ammonia, measure out, as before, a gallon of distilled water, and mix with it 50 septems of strong solution of ammonia (sp. gr. 0·88). Try whether 100 septems of the test-alkali thus prepared will neutralize 25 of the test-acid, proceeding according to the directions given subsequently as to the mode of testing. If the acid is just neutralized by the last few drops, the test-alkali is of the required strength. But if not, small additional quantities of water, or of strong ammonia solution, must be added, and fresh trials made, until the proper strength has been attained. The bottles in which the solution is stored should be filled nearly full and well stoppered.

"The mode of proceeding is as follows:—Take 50 septems of the test-acid (which is greatly in excess of any quantity of ammonia likely to be found in the gas), and pour it into the glass cylinder, so as to well wet the whole interior surface, and also the glass beads. Connect one terminal tube of the cylinder with the gas supply, and the other with the meter, and make the gas pass at a rate of not more than two-thirds of a cubic foot per hour. Any ammonia that is in the gas will be arrested by the sulphuric acid, and a portion of the acid (varying with the quantity of ammonia in the gas) will be neutralized thereby. At the end of each period of testing, wash out the glass cylinder and its contents with distilled water, and collect the washings in a glass vessel. Transfer one-half of this liquid to a separate glass vessel, and add a quantity of a neutral solution of litmus, or other indicator in ordinary use, just sufficient to colour the liquid. Then pour into the burette 100 septems of the test-alkali, and gradually drop this solution into the measured quantity of the washings collected, stirring constantly. As soon as the colour changes (indicating that the whole of the sulphuric acid has been neutralized), read off the quantity of liquid remaining in the burette. To find the number of grains of ammonia in 100 cubic feet of the gas, multiply by 2 the number of septems of test-alkali remaining in the burette, and move the decimal point one place to the left.

"The remaining half of the liquid is to be set aside, in case it should be desirable to repeat the volumetric analysis. This portion of the liquid is to be used in either of the two following cases:—

"1. If the analysis of the first portion of the liquid show an excess

of impurity, the Gas Examiner shall forthwith give the notice provided for in the Acts of Parliament (The Gaslight and Coke Company Act, 1876, sect. 40, and others); and if the Company think fit to be represented by some officer, the second portion of the liquid shall be examined in his presence.

"2. If the analysis of the first portion of the liquid should miscarry, or the Gas Examiner have any reason to distrust the result, he shall be at liberty to make an analysis of the second portion, provided that before doing so he give notice to the Company in order that they may, if they think fit, be represented by some officer.

"Unless thus used it is to be preserved, in a bottle properly labelled, for a week.

III. *Measurement of Gas and of the Rate of Flow.*

"The gas, which has been tested for Sulphuretted Hydrogen and Ammonia, shall pass next through a meter by means of which the rate of flow can be adjusted, and which is provided with a self-acting movement for shutting off the gas when ten cubic feet have passed, for stopping a clock so as to indicate the time at which the testings terminated, and for turning the tap of the recording Aerorthometer. The Gas Examiner shall enter in his book the time thus indicated, as also the time at which the testings began.

"The clock required is a good pendulum clock, with a wire passing transversely through the case behind the pendulum. Outside the case a lever arm is clamped to the wire, so that when liberated the arm will drop and turn the wire. Inside the case an arm is clamped to the wire, and at the end of the arm a flexible wire is fastened; when the lever drops, this flexible wire is brought into gentle frictional contact with the pendulum so as to stop it without shock.

"The clock should be wound from the front, and both hands should be mounted so that they can be set independently also from the front. It is desirable that the clock should be able to go for a week with one winding.

IV. *Sulphur Compounds other than Sulphuretted Hydrogen.*

"The testing shall be made in a room where no gas is burnt other than that which is being tested for sulphur and ammonia.

"The apparatus to be employed is represented by the diagram (Fig. 148), and is of the following description:—The gas is burnt in a small

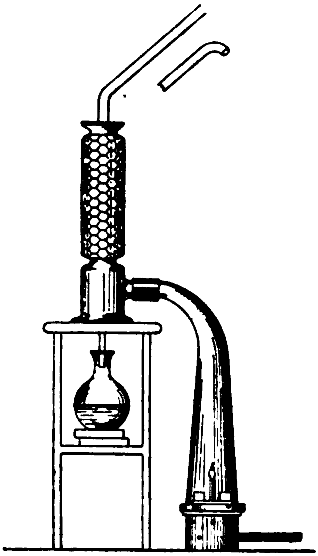


FIG. 148.

Bunsen burner with steatite top, which is mounted on a short cylindrical stand, perforated with holes for the admission of air, and having on its upper surface a deep circular channel to receive the wide end of a glass trumpet-tube.

"Pieces of sesqui-carbonate of ammonia, from the surface of which any efflorescence has been removed, are to be placed round the stem of the burner. The index of the meter is to be then turned forward to the point at which the catch falls, and will again support the lever tap in the horizontal position. The lever is then made to rest against the catch so as to turn on the gas. The index is then turned back to a little short of zero, and the burner lighted. When the index is close to zero the trumpet-tube is placed in position on the stand and its narrow end connected with the tubulure of the condenser. At the same time, the long chimney-tube is attached to the top of the condenser.

"As soon as the testing has been started, a reading of the Aerorthometer is to be made and recorded. The mechanism for stopping the clock is then to be connected with the lever tap of the meter, so that both may be stopped at the same moment, when ten cubic feet of gas have passed through the meter. The time at which the testing begins is to be recorded.

"After each testing, the flask or beaker which has received the liquid products of the combustion of the ten cubic feet of gas, is to be emptied into a measuring cylinder and then replaced to receive the washings of the condenser. Next the trumpet-tube is to be removed and well washed out into the measuring cylinder. The condenser is then to be flushed twice or thrice by pouring quickly into the mouth of it 40 or 50 cubic centimetres of distilled water. These washings are brought into the measuring cylinder, whose contents are to be well mixed and divided into two equal parts.

"One-half of the liquid so obtained is to be set aside, in case it

should be desirable to repeat the determination of the amount of sulphur which the liquid contains. This portion is to be examined under the same conditions as have been prescribed for the examination of the second portion of the liquid obtained from the apparatus used in testing for Ammonia; unless thus previously used, it is to be preserved, in a bottle properly labelled, for one week.

"The remaining half of the liquid is to be put into a flask, or beaker covered with a large watch-glass—treated with hydrochloric acid sufficient in quantity to leave an excess of acid in the solution—and then raised to the boiling point. An excess of a solution of barium chloride is now to be added, and the boiling continued for five minutes. The vessel and its contents are to be allowed to stand till the barium sulphate settles at the bottom of the vessel, after which the clear liquid is to be as far as possible poured off through a paper filter. The remaining liquid and barium sulphate are then to be poured on to the filter, and the latter well washed with hot distilled water. (In order to ascertain whether every trace of barium chloride and ammonium chloride has been removed, a small quantity of the washings from the filter should be placed in a test-tube, and a drop of a solution of silver nitrate added; should the liquid, instead of remaining perfectly clear, become cloudy, the washing must be continued until, on repeating the test, no cloudiness is produced.) Dry the filter with its contents, and transfer it into a weighed platinum crucible. Heat the crucible over a lamp, increasing the temperature gradually, from the point at which the paper begins to char, up to bright redness. When no black particles remain, allow the crucible to cool; place it when nearly cold in a desiccator over strong sulphuric acid, and again weigh it. The difference between the first and second weighings of the crucible will give the number of grains of barium sulphate. Multiply this number by 11 and divide by 4; the result is the number of grains of sulphur in 100 cubic feet of the gas.

"This number is to be corrected for the variations of temperature and atmospheric pressure in the manner indicated under the head of Illuminating Power, with this difference, that the mean of the Aerorthometer readings found at the beginning and at the end of any testing shall be taken as the reading for that testing. The reading at the beginning of the testing is to be made by the Gas Examiner, who, before leaving the testing place, will set the columns of mercury

level in the two tubes of the instrument, and will connect the lever-tap of the Aerorthometer with that of the meter. The fall of the lever of the meter will release a similar lever turning a tap which closes the tube of the Aerorthometer. The reading of the Aerorthometer as it stood at the end of the testing will require a small correction for the difference in level of the mercury in the two tubes, which is to be made in the following manner :—

"Let R be the correct reading, r_1 the actual reading of the Aerorthometer, r_2 the reading of the companion tube, h the mean height of the Barometer in units of the Aerorthometer scale, a figure which will be printed on each instrument. Then

$$R = r_1 \times \frac{h + r_1 - r_2}{h}$$

"The correction by means of the Aerorthometer reading may be made most simply and with sufficient accuracy, in the following manner :—

"When the Aerorthometer reading is between ·955—·965, ·966—·975 ·976—·985, ·986—·995, diminish the number of grains of sulphur by 4, 3, 2, 1 per cent.

"When the Aerorthometer reading is between ·996—1·005, no correction need be made.

"When the Aerorthometer reading is between 1·006—1·015, 1·016—1·025, 1·026—1·035, increase the number of grains of Sulphur by 1, 2, 3 per cent.

"Example :—

Grains of Barium Sulphate from 5 cubic ft. of Gas	4·3	Aerorthometer reading 1·018
Multiply by 11, and divide by 4	11	
	4) 47·3	
Grains of Sulphur in 100 cubic ft. of Gas (uncorrected)	11·82	
Add $11·8 \times \frac{2}{100}$ =	·24	
Grains of Sulphur in 100 cubic ft. of Gas (corrected)...........	12·06	Result : 12·1 grs.

"The Aerorthometer reading is the reciprocal of the Tabular Number. The Gas Examiner shall, not less often than once a month, compare the Aerorthometer reading with the reciprocal of the Tabular Number deduced from observations of the Barometer and Thermometer, and if there is a difference of more than one-half per cent. the instruments are to be readjusted.

"*As to the Maximum Amounts of Impurity in each Form with which the Gas shall be allowed to be Charged.*

"*Sulphuretted Hydrogen.*—By the Acts of Parliament all gas supplied must be wholly free from this impurity.

"*Ammonia.*—The maximum amount of this impurity shall be 4 grains per 100 cubic feet.

"*Sulphur Compounds other than Sulphuretted Hydrogen.*—The maximum amount of sulphur with which gas shall be allowed to be charged shall be 17 grains in every 100 cubic feet of gas."

"*Times and Mode of Testing for Illuminating Power.*

"The standard to be used in testing the illuminating power of gas shall be a Pentane 10-candle Lamp, which has been examined and certified by the Gas Referees. A Fig. and description of the lamp is given at pages 330 and 331. The residue of pentane in the saturator shall, at least once in each calendar month, be removed. It shall not be used again in any testings.

"The pentane to be used in this lamp shall be prepared as described, and shall show when tested the properties specified.

"All pentane provided by the Gas Companies will be examined and certified by the Gas Referees, and will be sent to the testing places in one-pint cans, which have been both sealed and labelled by them; and no pentane shall be used in the testing places other than that which has been thus certified.

"The testings for illuminating power shall be three in number daily. But if the average of three testings falls below the prescribed illuminating power, a fourth testing shall be made.

"The Photometers to be used in the testing places shall be the Table Photometer.

"The several parts of the apparatus stand upon a well-made and firm table, 5 ft. 6 in. by 3 ft. 6 in., and 2 ft. 5 in. high. The upper surface of this table is smooth, level, and dead black. Upon this are placed or clamped in the positions shown:—

"(1) The Gas Meter; (2) The Gas Governor; (3) The Regulating Tap; (4) The 'Sugg's London Argand, No. 1' Burner; (5) The Connecting Pipes; (6) The Pentane Ten-Candle Lamp; (7) The Photoped; (8) The Aerorthometer; (9) The Stop-Clock; (10) Dark Screens.

[All these several parts are described in great detail in the notification.]

"The air-gas in the lamp is to be kept burning so that the flame is near its proper height for at least ten minutes before any testing is made. At the completion of every testing the air-gas is to be turned out; but, if the interval between two testings does not much exceed one hour and the Gas Examiner is present during the interval, he may, instead of turning it out, turn it down low.

"The gas-burner attached to each Photometer shall be a standard burner corresponding to that which has been deposited with the Warden of the Standards in accordance with Section 37 of The Gaslight and Coke Company Act, 1876. The following is a description of the standard burner to be used:—

"This was designed by Mr. Sugg, and was called by him 'Sugg's London Argand, No. 1.'

A full-sized section (here given half size) is appended (Fig. 149), in which A represents a supply pipe, B the gallery, C the cone, D the steatite chamber, E the chimney.

The following are the dimensions of those parts of the burner upon which its action depends:—

		Inch.
Diameter of supply-pipes . . .		0·08
External diameter of annular steatite chamber		0·84
Internal diameter of annular steatite chamber		0·48
Number of holes	24	
Diameter of each hole		0·045
Internal diameter of cone—		
At the bottom		1·5
At the top		1·08
Height of upper surface of cone and of steatite chamber above floor of gallery		0·75
Height of glass chimney . . .		6
Internal diameter of chimney . .		$1\frac{7}{8}$

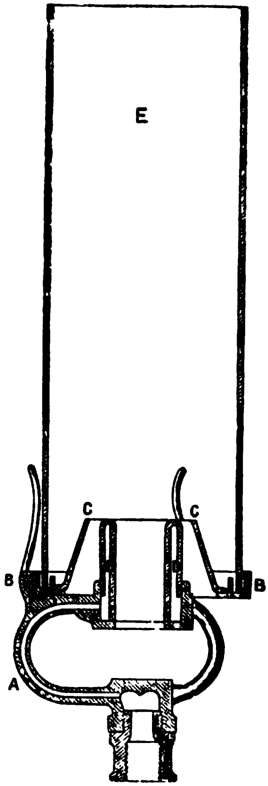


FIG. 149.

"Each burner shall bear a distinctive number. No burner shall be used for testing the illuminating power of gas that does not bear the lead seal of the Gas Referees.

"A clean chimney is to be placed on the burner before each testing.

"The gas under examination is to be kept burning, so that the flame is about the usual height, for at least fifteen minutes before any testing is made; and no gas shall pass through the meter attached to the Photometer except that which is consumed by the standard burner in testing or during the intervals between the testings made on any day, and that which is used in proving the meter.

"The paper used in the photoped of the Photometer shall be white in colour, unglazed, of fine grain, and free from water marks. It shall be as translucent as is possible consistently with its being sufficiently opaque to prevent any change in the apparent relative brightness of the two portions of the illuminated surface, when the head is moved to either side. This paper should, when not in use, be covered, to protect it from dust; and, if it has been in any way marked or soiled, a fresh piece is to be substituted.

"Each testing shall be made as follows:—

"The index of the regulating tap shall be so turned that the gas flame gives rather less light on the photoped than the standard, and shall then be gradually turned on until equal illumination has been obtained. The position of the index shall then be noted. Next, the tap shall be so turned that the gas flame appears to give rather more light than the standard, and shall then be turned off until equality is again attained, and the position of the index shall be again noted. The double operation shall be repeated. The mean of the four index positions shall be taken as that which gives true equality of illumination. The index shall be set to this mean position, the quality of illumination verified, and the time that the hand of the meter takes to make two complete revolutions shall be observed.

"In order to make this observation, a stop-clock shall be used, by which the time which has elapsed since the clock was started can be read with an accuracy of at least half a second. The clock shall be started at the moment when the meter-hand points either to zero or to some other convenient mark, and a note shall be immediately made of the mark chosen. Exactly at the completion of the second turn of the meter-hand the Gas Examiner shall stop the clock. The

time of two revolutions thus indicated by the clock is to be read to the nearest half second and found in the table, A, given herewith. From this and the reading of the Aerorthometer, or a determination of the tabular number, the illuminating power of the gas is to be obtained, either directly or by interpolation. Only one figure after the decimal point need be entered when the result is above 16; where a lower result is found, both figures should be noted and entered. A table, B, giving the Tabular Numbers for different temperatures and pressures is appended.

"The method of finding the illuminating power from the table by interpolation, may be illustrated by the two following examples:—

"I. Time 1 min. 53 sec. Reading of Aerorthometer, 1·073. By the table the illuminating power corresponding to this time of consumption and to the reading 1·070 is 16·12, while for the reading 1·080 it is 16·27. Thus, in this part of the scale, when the reading is 10 degrees higher the illuminating power is greater by 0·15 candle. Hence, when the reading is 3 degrees above 1·070, the corresponding illuminating power is $16{\cdot}12 + \frac{3}{10} \times 0{\cdot}15 = 16{\cdot}165$ candles and the number to be returned is 16·2.

"II. Time 2 min. 1½ sec. Reading of Aerorthometer, ·984. The numbers in the table under ·980 are 15·81 for 2 min. 1 sec., and 15·94 for 2 min. 2 secs.; therefore the number corresponding to 1½ sec. is the half-way number 15·875; the number found similarly under ·990 is 16·035. The increase for 10 degrees is here 0·16; the number corresponding to the reading ·984 is accordingly $15{\cdot}875 + \frac{4}{10} \times 0{\cdot}16 = 15{\cdot}939$; and the number to be returned is 15·94.

"If, in very exceptional circumstances, the Aerorthometer scale or the tables do not include the conditions that are met with, the Gas Examiner shall determine the illuminating power by means of one or other of the formulæ printed below the tables.

"The Gas Examiner shall, at least once a week, compare the stop-clock with the standard clock in each testing place.

"The Gas Examiner shall enter in his book the particulars of every testing of illuminating power made by him at the testing places, during or immediately after such testing; and in the case of any testing which he rejects he shall also state the cause of rejection. No testing is to be rejected on the ground that the result seems improbable."

TABLE A, giving the ILLU ield the Light of 16 Candles, and from Readings
Barometer, The through the meter of one-sixth of a cubic foot of g
be found in th lines. In the corresponding line and column is fo
Illuminating Po

Aerorthometer		1·050	1·060	1·070	1·080	1·090	1·100	1·110
Tabular Number		·953	·944	·935	·926	·918	·909	·901
Minute.	Seconds.							
1	44	14·56	14·70	14·84	14·98	15·11	15·25	15·39
	45	14·70	14·84	14·98	15·12	15·26	15·40	15·54
	46	14·84	14·98	15·12	15·26	15·41	15·55	15·69
	47	14·98	15·12	15·27	15·41	15·55	15·69	15·84
1	48	15·12	15·26	15·41	15·55	15·70	15·84	15·98
	49	15·26	15·41	15·55	15·70	15·84	15·99	16·13
	50	15·40	15·55	15·69	15·84	15·99	16·13	16·28
	51	15·54	15·69	15·84	15·98	16·13	16·28	16·43
1	52	15·68	15·83	15·98	16·13	16·28	16·43	16·58
	53	15·82	15·97	16·12	16·27	16·42	16·57	16·72
	54	15·96	16·11	16·26	16·42	16·57	16·72	16·87
	55	16·10	16·25	16·41	16·56	16·71	16·87	17·02
1	56	16·24	16·39	16·55	16·70	16·86	17·01	17·17
	57	16·38	16·54	16·69	16·85	17·00	17·16	17·32
	58	16·58	16·68	16·83	16·99	17·15	17·31	17·46
	59	16·66	16·82	16·98	17·14	17·29	17·45	17·61
2	0	16·80	16·96	17·12	17·28	17·44	17·60	17·76
2	1	16·94	17·10	17·26	17·42	17·59	17·75	17·91
	2	17·08	17·24	17·41	17·57	17·73	17·89	18·05
	3	17·22	17·38	17·55	17·71	17·88	18·04	18·20
	4	17·36	17·53	17·69	17·86	18·02	18·19	18·35
2	5	17·50	17·67	17·83	18·00	18·17	18·33	18·50
	6	17·64	17·81	17·98	18·14	18·31	18·48	18·65
	7	17·78	17·95	18·12	18·29	18·46	18·63	18·80
	8	17·92	18·09	18·26	18·43	18·60	18·77	18·94
2	9	18·06	18·23	18·40	18·58	18·75	18·92	19·09
	10	18·20	18·37	18·55	18·72	18·89	19·07	19·24
	11	18·34	18·51	18·69	18·86	19·04	19·21	19·39
	12	18·48	18·66	18·83	19·01	19·18	19·36	19·54

$$\frac{\text{Time in Seconds.}}{7\cdot5 \times \text{Tabular Number.}}$$

atures, and under different Atmospheric Pressures.

Bar.	Ther. 40°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°
28·0	·979	917	·912	·907	·902	·897	·892	·887	·881	·875	·870
28·1	·983	921	·916	·911	·905	·900	·895	·890	·884	·879	·873
28·2	·986	924	·919	·914	·909	·904	·898	·893	·887	·882	·876
28·3	·990	928	·922	·917	·912	·907	·902	·896	·891	·885	·880
28·4	·993	931	·926	·921	·915	·910	·905	·900	·894	·888	·883
28·5	·997	934	·929	·924	·919	·914	·908	·903	·897	·892	·886
28·6	1·001	938	·932	·927	·922	·917	·912	·906	·901	·895	·889
28·7	1·004	941	·936	·931	·925	·920	·915	·909	·904	·898	·893
28·8	1·007	1944	·939	·934	·929	·924	·918	·913	·907	·901	·896
28·9	1·011	1948	·942	·937	·932	·927	·921	·916	·910	·905	·899
29·0	1·014	1951	·946	·941	·935	·930	·925	·919	·914	·908	·903
29·1	1·018	1954	·949	·944	·939	·933	·928	·923	·917	·911	·906
29·2	1·021	1958	·952	·947	·942	·937	·931	·926	·920	·914	·909
29·3	1·025	1961	·956	·950	·945	·940	·935	·929	·923	·918	·912
29·4	1·028	1964	·959	·954	949	·943	·938	·932	·927	·921	·915
29·5	1·032	1968	·962	·957	·952	·947	·941	·936	·930	·924	·919
29·6	1·036	1971	·966	·960	·955	·950	·944	·939	·933	·927	·922
29·7	1·039	1974	·969	·964	·959	·953	·948	·942	·937	·931	·925
29·8	1·043	1978	·972	·967	·962	·957	·951	·946	·940	·934	·928
29·9	1·046	1981	·976	·970	·965	·960	·954	·949	·943	·937	·932
30·0	1·050	1985	·979	·974	·968	·963	·958	·952	·946	·941	·935
30·1	1·053	1988	·983	·977	·972	·966	·961	·955	·950	·944	·938
30·2	1·057	1991	·986	·980	·975	·970	·964	·959	·953	·947	·941
30·3	1·060	1995	·989	·984	·978	·973	·968	·962	·956	·950	·945
30·4	1·064	1998	·993	·987	·982	·976	·971	·965	·959	·954	·948
30·5	1·067	1·001	·996	·990	·985	·980	·974	·969	·963	·957	·951
30·6	1·071	1·005	·999	·994	·988	·983	·977	·972	·966	·960	·954
30·7	1·074	1·008	1·003	·997	·992	·986	·981	·975	·969	·963	·957
30·8	1·078	1·011	1·006	1·000	·995	·990	·984	·978	·972	·967	·961
30·9	1·081	1·015	1·009	1·004	·998	·993	·987	·982	·976	·970	·964
31·0	1·085	1·018	1·013	1·007	1·002	·996	·991	·985	·979	·973	·967

*** The numbene height of the barometer in inches, *t* the temperature on the Fahrenheit scale, and *a* the ld V the corresponding volume at 60° and 30 inches pressure, V=*rn*.

MODE OF TESTING THE PRESSURE AT WHICH GAS IS SUPPLIED.

"Testing of pressure shall be made by unscrewing the Governor and Burner of one of the ordinary public lamps, in such street or part of a street as the Controlling Authority may from time to time appoint, and attaching in their stead a portable pressure gauge.

"Each testing place is provided with a gauge prescribed for this purpose by the Referees, consisting of an ordinary pressure gauge inclosed in a lantern, which also holds a candle for throwing light upon the tubes and scale. The difference of level of the water in the two limbs of the gauge is read by means of a sliding scale, the zero of which is made to coincide with the top of the lower column of liquid.

"The Gas Examiner having fixed the gauge gas-tight, and as nearly as possible vertical on the pipe of the lamp, and having opened the cocks of the lamp and gauge, shall read and at once record the pressure shown. From the observed pressure one-tenth of an inch is to be deducted to correct for the difference between the pressure of gas at the top of the lamp column and that at which it is supplied to the basement of neighbouring houses.

THE GAS REFEREES' STREET LAMP PRESSURE GAUGE.

"This instrument (Fig. 150) has been designed by the Gas Referees, in accordance with Section 6 of The Gaslight and Coke and other Gas Companies Acts Amendment Act, 1880, for the purpose of testing in any street at any hour the pressure at which gas is supplied. Its construction and mode of use are as follows :—

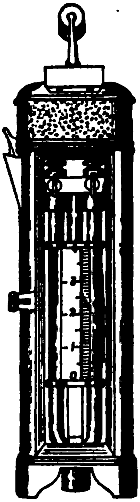


FIG. 150.

"Within a lantern provided with a handle for carrying and feet for resting on the ground, is placed a candle-lamp, to give light for reading the gauge. In front of the candle-lamp is a sheet of opal glass, and in front of this a glass U-tube, partly filled with coloured water, and communicating at one end with the air, at the other with a metal pipe, which passes through the bottom of the lantern. In order to read easily and accurately the difference of level of the liquid in the two limbs, a scale divided into tenths of an inch is made to slide between them with sufficient friction to retain it in any position. The zero of the scale having been brought level with the surface of the liquid which is pressed upon by the gas, the height

above this of the surface which is pressed upon by the air can be read directly. The lantern is closed in front by a glass door, at each side of which is a reflector for throwing light upon the scale of the gauge. Above each limb of the U-tube is a tap, which can be closed when the instrument is not in use, to prevent the liquid being accidentally spilt.

"To make a testing of pressure the governor and burner of a street lamp are to be removed, and the pressure gauge is to be screwed on to the gas pipe, by which it is supported. The cock is then turned on, and a reading made. If on turning off the cock the level of the liquid is unchanged, or changes slowly, the reading is correct; but if the level changes quickly, the junction between the lamp and the gauge must be made more perfect, and the testing repeated. A small leakage is immaterial, provided the cock is turned fully on.

"The pressure at the top of the lamp column is greater by about 0·1 inch than that at the main, which is the pressure required. Accordingly a deduction of 0·1 inch from the observed pressure is to be made.

METERS.

"Each of the meters used for measuring the gas consumed in making the various testings is constructed with a measuring drum which allows one-twelfth of a cubic foot of gas to pass for every revolution. A hand is fastened directly to the axle of this drum, and passes over a dial divided into one hundred equal divisions. The dial and hand are protected by a glass. In the meter employed in testing the purity of gas, the pattern of dial for showing the number of revolutions and the automatic cut-off hitherto in use shall be retained, but in the meter employed for testing illuminating power, only the dial above described is needed. The stop-cock may be either attached to the meter or separate.

"The meters used for measuring the gas consumed in making the various testings, having been certified by the Referees, shall, at least once in seven days, be proved by the Gas Examiners by means of the Referees' one-twelfth of a cubic foot measure. A description of this instrument, with directions how to use it, is here given.

"No meter other than a wet meter shall be used in testing the gas under these instructions.

THE GAS REFEREES' ONE-TWELFTH OF A CUBIC FOOT MEASURE.

"This instrument is represented in Fig. 150A; it consists of a vessel of blown glass of a cylindrical form, with rounded ends, terminating in short tubes about 40 millimetres in diameter outside, which tubes are reduced at their outer ends to about 20 millimetres in diameter outside. Lines are etched round each tubular neck in such positions that the capacity of that portion of the vessel included between these marks is exactly one-twelfth of a cubic foot when the glass is at the ordinary temperature. No correction is needed for the cubical expansion of the glass. The two tubular necks of the instrument pass through two boards placed below and parallel to the top of a small four-legged table. For convenience, the upper one of these two boards is made in two parts, and hinged to the legs.

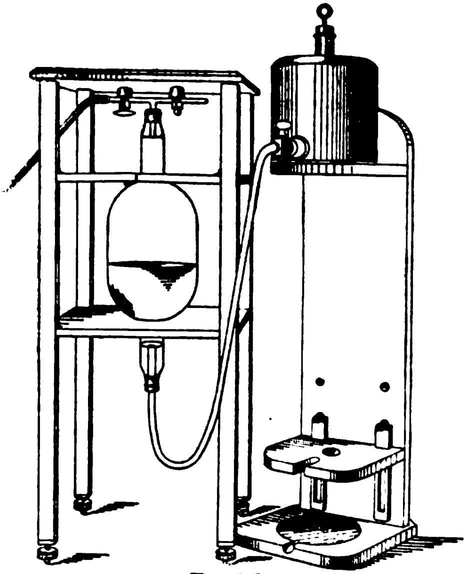


FIG. 150A.

"Into each end of the instrument a glass tube, about 8 millimetres in diameter outside, is fitted, gas and water tight, by means of india-rubber corks, in such positions that the inner end of the upper tube lies exactly in the plane of the mark at its end of the instrument, while that of the lower is about 1 mm. below the mark.

"The upper tube terminates in a T, each branch of which is provided with a stop-cock.

"A separate stand carries two shelves, the upper one about 40 millimetres below the level of the upper mark, and the lower one below the level of the lower mark. The lower shelf is adjustable, and must be so placed that the action about to be described shall take place.

"A water-vessel is provided having a capacity of about one-tenth

of a cubic foot.[1] It should be made of brass or copper, tinned on the inside. It has a tubulure near the bottom, to which is fitted a metal tap. The end of the tap is to be turned slightly downwards, and is to have a diameter outside of about 8 millimetres. The size of the way through the tap and of the connections is such that when a meter is being proved in the manner to be described, the water fills the instrument from one mark to the other in about one minute. The water vessel has a tubulure in the cover, to which a narrow glass tube is fitted by means of a cork, so that air may enter or escape. The end of the tube is bent round upon itself in the form of a crook, so as to exclude dust and dirt. An india-rubber tube connects the tube at the base of the measure with the stop-cock of the water vessel. An ordinary chemical thermometer is provided for taking the temperature of the water.

"The pipe supplying gas to each meter is provided, near the meter, with a three-way stop-cock carrying a short branch pipe, so formed that it either connects the gas supply only with the branch pipe, the meter only with the branch pipe, or the gas supply with the meter, in which latter case the branch pipe is cut off from both. The index of the tap shows which communication is open. In order to avoid sending the gas used in proving the sulphur meter through the sulphuretted hydrogen and ammonia apparatus, a separate gas supply is provided. The branch pipe is so shaped as to be convenient for the attachment of an india-rubber tube.

"In order to put the instrument in adjustment the water vessel is placed upon the upper shelf, the water is poured into it until it rises about one-quarter of an inch in the upper narrow tube. One branch of the glass T is then connected by an india-rubber pipe with the branch of the three-way stop-cock. This is now turned so as to connect the branch pipe with the gas supply, and the water vessel is placed on the lower shelf. The water will run back into the vessel. The flow should cease when the water has just begun to descend in the lower tube; if not, the height of the lower shelf must be adjusted until this is the case.

"The space above the upper mark is always filled with gas, and that below the lower mark with water, so that the capacity of these portions of the instrument has no effect upon the measurements. The narrow tubes are so small that a variation of even an inch of the level at which the water stands in them has no appreciable effect upon the meter reading.

"The apparatus shall only be used in proving a meter when the temperature of the meter, and of the water in the water vessel, have been found not to differ by more than two degrees Fahrenheit.

"In order to prove the meters used in the various testings, the position of the index is taken when the instrument has been put in adjustment and filled with gas as described. The tap of the water vessel is turned off, and the pressure of the gas in the instrument reduced to atmospheric pressure by momentarily opening the tap in the free branch in the glass T. The water vessel is placed upon the upper shelf, its tap turned on, and one-twelfth of a cubic foot of gas is discharged through the meter. Fig. 150A represents this operation in progress. The three-way stop-cock is then turned so as to fill the instrument with gas which is reduced to atmospheric pressure as before, and a second, and again a third quantity is discharged through the meter. Should the hand attached to the axle of the measuring drum have travelled in the three revolutions as much as one division beyond the point from which it started, some water must be removed from the meter; if the travel of the meter hand is as much as one division short of this point, some water must be poured in. The operation is then to be repeated until the error is found to fall within the specified limits."

ILLUMINATING POWER.

For testing the illuminating power of gas in accordance with the general statutory provisions the Bunsen photometer is used; and the Letheby-Bunsen (Fig. 151) or the Evans enclosed form of the apparatus is that generally adopted.

The standard candle is a sperm candle, six of which weigh 1 lb., and each burns 120 grains of sperm per hour.

The gas is supplied through an experimental meter, and burns at one end of a graduated bar, and the candle at the other; a moveable disc of prepared paper being placed between the two.

This disc, which is contained within a sliding box or carriage, fitted with two reflectors, is moved between the two lights until its opposite sides are equally illuminated, whereupon the illuminating power of the gas is read off by the operator on inspection of the figures on the graduated bar.

The bar is graduated in accordance with the law that lights which equally illuminate an object are to each other as the square of their distance from such object. Thus, assuming that the distance from

the disc to the gas flame is 80 inches, and to the candle flame 20 inches, then $80^2 = 6400$, and $20^2 = 400$, or as 16 to 1, the illuminating value of the gas as compared with the candle.

The following apparatus are also required, viz.:—A governor to regulate the gas pressure; a clock striking every minute; a King's pressure-gauge; a candle balance and weights; a thermometer and a barometer.

The apparatus is arranged and fixed on a substantially-made table, placed in the photometer room. This room may be conveniently made

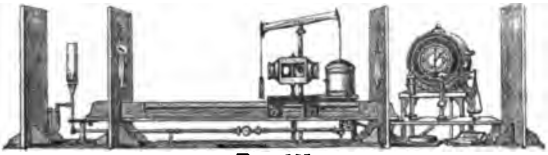


FIG. 151.

about 10 or 12 feet square, and should be ventilated; but currents of air which would affect the steadiness of the gas and candle flame must be guarded against. Provision is made to exclude the daylight; and the walls are coloured a dull black.

Statutory Regulations for Testing the Illuminating Power of Gas.

The provisions in Schedule A of the Gas-Works Clauses Act, 1871, in regard to the apparatus for, and the mode of testing the Illuminating Power of gas, are as follows:—

Regulations in respect of Testing Apparatus.

"The apparatus for testing the illuminating power of the gas shall consist of the improved form of Bunsen's photometer, known as Letheby's open 60-inch photometer, or Evans's enclosed 100-inch photometer, together with a proper meter, minute clock, governor, pressure gauge, and balance.

"The burner to be used for testing the gas shall be such as shall be prescribed.

"The candles used for testing the gas shall be sperm candles of six to the pound, and two candles shall be used together."

Mode of Testing for Illuminating Power.

The gas in the photometer should be lighted at least fifteen minutes before the testings begin and kept continuously burning from the beginning to the end of the tests.

Each testing should include ten observations of the photometer, made at intervals of a minute

The consumption of the gas should be carefully adjusted to 5 cubic feet per hour.

The candles are lighted at least ten minutes before beginning each testing, so as to arrive at their normal rate of burning, which is shown when the wick is slightly bent, and the tip glowing. The standard rate of consumption for the candles is 120 grains each per hour. Before and after making each set of ten observations of the photometer, the Gas Examiner weighs the candles; and if the combustion shall have been more or less per candle than 120 grains per hour, he makes the calculations requisite to neutralize the effects of this difference.

The average of each set of ten observations is taken as representing the illuminating power of that testing.

The disc used in the Photometer is either the Leeson or the Bunsen disc. The chimneys should be cleaned daily.

The rate of burning of the gas in each burner should be 5 cubic feet per hour—a rate of consumption which is shown by the long hand of the meter making exactly one revolution per minute for several minutes consecutively.

Instead of weighing the candles, the Examiner may observe the time in which 40 grains are burnt. This should not exceed 10·5, or fall short of 9·5 minutes.

At the time of each testing the Examiner observes and records the temperature of the gas, as shown by the thermometers attached to the meters, and also the height of the barometer. The volumes of the gas operated upon during the testings may be corrected from these data (the standard of comparison being, for the barometer, 30 inches, and for the thermometer, 60 degrees) by means of the Table B (*ante*). Suppose, for example, the thermometer stands at 54 degrees, and the barometer at 30·3 inches: multiply the quantity of gas consumed by the corresponding *tabular number*—the product will be the corrected volume of the gas—*i.e.*, the volume the gas would have occupied when measured over water at the standard temperature and pressure. Thus—

Volume of gas consumed . . . . 5 cubic feet.
Tabular number for barometer and thermometer 1·025.

Then $1{\cdot}025 \times 5 = 5{\cdot}125$, the corrected volume.

Instead of thus correcting the volume of gas consumed, the same object may be attained by dividing the observed illuminating power by the tabular number.

The calculations for working out the corrections, &c., for the illuminating power of the gas proceed in the following manner:—Add the observations together, and divide the sum by 10 to get the average; then as two candles are used, multiply by two, to get the illuminating power of the gas if tried against one candle. Then, as the standard rate of the consumption of the candles (viz., 120 grains) is to the average number of grains consumed by each per hour, so is the above-obtained number to the actual illuminating power. Finally, the correction for temperature and pressure is made by dividing the illuminating power by the tabular number. For example (taking the tabular number as 1·025):—

Observations—

1st minute	7·8	Consumption of the 2 candles in
2nd „	7·8	10 minutes,
3rd „	8·1	= 41 grains.
4th „	8·2	3
5th „	8·3	——
6th „	8·5	123 = consumption of 1 candle
7th „	8·6	per hour.
8th „	8·4	
9th „	8·3	
10th „	8·6	

10)82·6
Average, by 2 candles = 8·26
2

Average, by 1 candle = 16·52
Consumption by 1 candle per hour } 123 grains.

4956
3304
1652

Standard consumption . 120)203196

Correction for temp. & pres. 1025)16933(16·5 = corrected Illum. Power in candles.
1025

6683
6150

5330

The foregoing calculation can be shortened as follows:—

Average, by 2 candles . . . . = 8·26
Consumption by 2 candles in 10 minutes 41 grains.

826
3304

2) 33866

Tabular number . . 1025) 16933 (16·5 = corrected Illum. Power in candles.
1025

6683
6150

5330

PHOTOMETER TABLE.

*Calculated for One Candle. (Sugg.)**

Consumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	110	111	112	113	114	115	116	117	118
4·5	1·01851	1·02777	1·03703	1·04629	1·05555	1·06481	1·07407	1·08333	1·09259
4·6	·99637	1·00543	1·01449	1·02355	1·03260	1·04166	1·05072	1·05978	1·06884
4·7	·97517	·98404	·99290	1·00177	1·01063	1·01950	1·02836	1·03723	1·04609
4·8	·95486	·96354	·97222	·98090	·98958	·99826	1·00694	1·01562	1·02430
4·9	·93537	·94387	·95238	·96088	·96938	·97789	·98639	·99489	1·00340
5·0	·91666	·92500	·93333	·94166	·95000	·95833	·96666	·97499	·98333
5·1	·89869	·90686	·91503	·92320	·93137	·93954	·94771	·95588	·96405
5·2	·88141	·88942	·89743	·90544	·91346	·92147	·92948	·93750	·94551
5·3	·86477	·87264	·88050	·88836	·89622	·90408	·91194	·91981	·92767
5·4	·84876	·85648	·86419	·87191	·87962	·88734	·89506	·90277	·91049
5·5	·83333	·84090	·84848	·85606	·86363	·87121	·87878	·88636	·89393

Consumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	119	120	121	122	123	124	125	126	127
4·5	1·10185	1·11111	1·12037	1·12962	1·13888	1·14814	1·15740	1·16666	1·17592
4·6	1·07789	1·08695	1·09601	1·10507	1·11413	1·12318	1·13224	1·14130	1·15036
4·7	1·05496	1·06383	1·07269	1·08156	1·09042	1·09929	1·10815	1·11702	1·12588
4·8	1·03298	1·04166	1·05034	1·05902	1·06770	1·07638	1·08506	1·09375	1·10243
4·9	1·01190	1·02040	1·02891	1·03741	1·04591	1·05442	1·06292	1·07142	1·07993
5·0	·99166	1·00000	1·00833	1·01666	1·02499	1·03333	1·04166	1·04999	1·05832
5·1	·97222	·98039	·98856	·99673	1·00490	1·01307	1·02124	1·02941	1·03758
5·2	·95352	·96153	·96955	·97756	·98557	·99358	1·00160	1·00961	1·01762
5·3	·93553	·94339	·95125	·95911	·96698	·97484	·98270	·99056	·99842
5·4	·91820	·92592	·93364	·94135	·94907	·95679	·96450	·97222	·97993
5·5	·90151	·90909	·91666	·92424	·93181	·93939	·94696	·95454	·96212

Consumption of Gas Feet per Hour.	Grains per Hour Consumed by the Sperm Candle.								
	128	129	130	131	132	133	134	135	..
4·5	1·18518	1·19444	1·20370	1·21296	1·22222	1·23148	1·24074	1·25000	..
4·6	1·15942	1·16847	1·17753	1·18659	1·19565	1·20471	1·21376	1·22282	..
4·7	1·13475	1·14361	1·15248	1·16134	1·17021	1·17907	1·18794	1·19680	..
4·8	1·11111	1·11979	1·12847	1·13715	1·14583	1·15451	1·16319	1·17187	..
4·9	1·08843	1·09693	1·10544	1·11394	1·12244	1·13095	1·13945	1·14795	..
5·0	1·06666	1·07500	1·08333	1·09166	1·10000	1·10833	1·11666	1·12500	..
5·1	1·04575	1·05392	1·06209	1·07026	1·07843	1·08660	1·09477	1·10294	..
5·2	1·02564	1·03365	1·04166	1·04967	1·05769	1·06570	1·07371	1·08173	..
5·3	1·00628	1·01415	1·02201	1·02987	1·03773	1·04559	1·05345	1·06132	..
5·4	·98765	·99537	1·00308	1·01080	1·01851	1·02623	1·03395	1·04166	..
5·5	·96969	·97727	·98484	·99242	1·00000	1·00757	1·01515	1·02272	..

* Mr. Sugg has also published, in book form, a series of useful photometrical tables from 9·5 to 20 candles.

RULE.—Multiply the number standing beneath the number of grains consumed by the candle, and opposite the number of feet consumed by the gas-burner, by the illuminating power as read off from the scale of the photometer; the product is the correct value of the gas reduced to the standard of 120 grains per hour and 5 cubic feet per hour.

THE AERORTHOMETER.

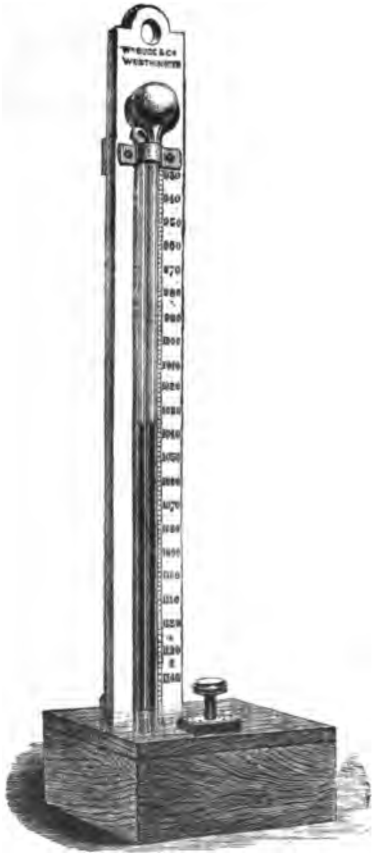


FIG. 152.

The Aerorthometer (Fig. 152) invented by Mr. A. Vernon Harcourt, is an ingenious instrument for correcting the observed volume of any portion of gas to its normal volume —*i.e.*, the volume it would have under standard conditions of temperature and pressure. A reading of this instrument furnishes a number expressing the ratio between the observed and the normal, or corrected, volumes of any gas, and serves instead of reading a barometer and thermometer and calculating or referring to a table.

It consists of a bulb and stem, like a thermometer, containing air enclosed over mercury. The mercury stands at a certain height in the stem, and rises and falls as the enclosed air contracts or expands with changes of temperature and atmospheric pressure. The volume of the air is read off by means of a scale engraved on the stem and on the wood behind it. Each degree of the scale marks a portion of the stem whose capacity is one-thousandth part of the volume of the enclosed air when under a pressure

of 30 inches of mercury and at a temperature of 60° Fahr. The line at which the mercury stands under these conditions is figured accordingly 1000; and any other reading of the instrument, at a different pressure or temperature, gives the volume to which the thousand volumes have been expanded or contracted. A small drop of water having been passed into the bulb, the expansion caused by a rise of temperature includes that due to the increased tension of aqueous vapour.

In order that the volume of air enclosed in the bulb of the Aerorthometer may be measured under the atmospheric pressure, a second tube is placed by the side of the graduated stem, which is of the same calibre and connected with the same reservoir of mercury, but open above. By the pressure of a screw upon the leathern top of the reservoir, the mercury is raised in both tubes; and when the mercury stands at the same level in both, the enclosed air is under the atmospheric pressure. By being painted white, the bulb is protected from the action of radiant heat.

Since the volume of any portion of gas contained in a holder or passing through a meter near which an Aerorthometer is placed, bears the same relation to the volume the gas would occupy under standard conditions as the volume read on the stem of the Aerorthometer bears to 1000, the figures expressing the corrected volume of the gas may be obtained by multiplying the observed volume by 1000, and dividing it by the Aerorthometer reading. Thus, if n represents the number read upon the instrument, v the observed volume or rate of passage of the gas, and V the corrected or normal value, then

$$V = v\frac{1000}{n}.$$

The instrument must stand or be suspended in a vertical position near the meter or holder whose registration it is to be used to correct. To make a reading, the screw is to be turned (if necessary) until the mercury stands at a lower level in the open tube than in that which is graduated. Then the screw must be turned slowly in the opposite direction until the mercury is exactly level in both tubes. The level of the mercury read upon the graduated tube gives the required number.

FOREIGN AND OTHER (PROPOSED) HOME STANDARDS OF LIGHT.

The sperm candle has long been considered an unsatisfactory standard, owing chiefly to the shade of colour emitted by it differing somewhat from that of the gas, and the inequality of its rate of consumption.

Various standards of light have been advocated from time to time to supersede the candle; but none of these have hitherto been adopted in this country.

The Carcel lamp is the standard in France; the light, equal to 9·6 standard sperm candles, being produced by purified colza (rape) oil, burning at the rate of 648 grains per hour. The upper portion of this lamp is shown in section in Fig. 153; and the dimensions of its various parts are as follows:—

Fig. 153.

External diameter of burner .	·9055 inches.
Internal diameter of air-tube .	6·692 ,,
External diameter of air-tube .	1·7912 ,,
Total length of chimney . .	11·4170 ,,
Length from base to neck of chimney	2·4015 ,,
External diameter of chimney at level of neck	1·8503 ,,
External diameter of chimney at top.	1·3385 ,,
Mean thickness of the glass .	·0787 ,,

The wick used is that known as "light-house wick," and the plait is composed of 75 strands; a piece 4 inches long weighing 55·5 grains. When the consumption of oil is less than 586 grains, or exceeds 710 grains per hour, the trial is cancelled.

The German normal paraffin candle is equal to 1·05 standard sperm candles. It has a diameter of 20 millimetres, and is made of the purest possible paraffin, with an addition of 2 per cent. of stearine. Its wick is of 24 cotton threads plaited as uniformly as possible.

The Hefner-Altenick unit equals 0·88 standard sperm candle, being the illuminating power of a freely burning flame, in still pure air, supplied by a section of solid wick, and fed with amyl-acetate; the wick-tube being circular, and of German silver, measuring

8 millimetres internal and 8·3 millimetres external diameter, and 25 millimetres high; the flame being 40 millimetres high, measured from the edge of the wick-tube, at least ten minutes after lighting the lamp.

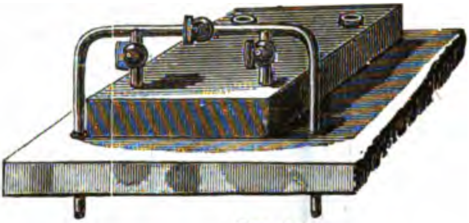


Fig. 155.

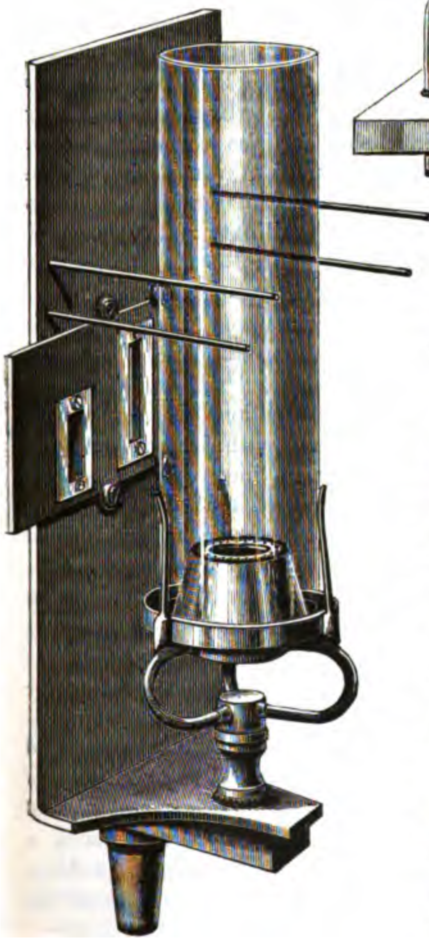


Fig. 154.

Mr. Keates invented a moderator lamp consuming sperm oil, and yielding a light equal to 10 sperm candles, which he advocated as a suitable standard.

The most ingenious standard proposed is that of a portion of the gas-flame itself. The credit of the conception is shared by both Mr. Fiddes and Mr. John Methven, who, unaware of each other's investigations, conducted a series of experiments on the same lines.

In the course of his photometrical observations, Mr. Fiddes found that if a circular hole about $\frac{1}{4}$-inch diameter were made at a given height in an opaque chimney, and this placed over an argand flame in lieu of the usual glass chimney, the amount of light passing through the hole was a constant quantity, notwithstanding variations in the illuminating power of the gas.

Mr. Methven's researches led him to a similar conclusion; his later experiments showing that the amount of light (equal to two standard

candles), passing through a slot 1 inch long and $\frac{1}{4}$ inch wide, in an opaque screen, is constant with gases ranging from 15 to 20 candles power; and that, when either common or cannel gas is carburetted with gasoline (light petroleum spirit, boiling point below 120° Fahr.), the amount of light yielded by a flame $2\frac{1}{4}$ inches long is constant, whatever the illuminating power of the gas employed. As the result of this latter discovery, Mr. Methven uses a shorter and wider slot for the carburetted gas. Fig. 154 shows the Methven standard with the long and short slots combined on the same slide for the ordinary and carburetted gas respectively. Fig. 155 shows the carburettor fitted with bye-pass arrangement, so that when connected to the gas-pipe supplying the Methven standard, either ordinary gas or carburetted gas may be used. Photometrical observations are greatly simplified by the ease with which it can be used, the saving of time which it effects, and the avoidance of that distraction of mind on the part of the operator which is inseparable from the employment of candles.

FIG. 156.

In the Pentane standard of Mr. A. Vernon Harcourt, the gas employed for producing the light is "a mixture of air with that portion of American petroleum which, after repeated rectification, distils at a temperature not exceeding 122° Fahr. The liquid thus obtained consists almost entirely of pentane, the fifth member of the series of paraffines." Burning at the rate of $\frac{1}{2}$ a cubic foot per hour, this gas gives a flame which yields a light equal to that of the standard candle.

Mr. Harcourt has devised a new Pentane standard lamp on a different principle to that above referred to, in which, instead of a mixture of pentane and air, pentane only is burned.

The lamp, shown in Fig. 156, resembles an ordinary spirit lamp, with the chimney added to keep the flame steady, and raise the temperature of combustion. A wick is employed, not, as in the ordinary lamp, at the point of ignition, but several inches from it; its use being to convey the liquid pentane by capillary action to the part of the tube where volatilization of the pentane takes place by the warmth conducted downwards from the flame. The wick is enclosed in a tube jacketed by another tube to produce a steady temperature; and this again is covered by the larger tube with the contracted upper end, as shown. The chimney is moveable for adjustment at any required height.

To put the lamp in action, first remove the lower tube, and having warmed the inner tubes, light the pentane vapour, as it rises in the smaller one. Put on the large tube with the chimney attached; and the top of the flame, on raising the wick slightly, will pass into the chimney.

Two narrow slots are cut in the chimney on opposite sides, so that the tip of the flame is visible through either of them. When the chimney is set at a definite height above the lower tube, and the flame is adjusted so that its tip is between the upper and lower limits of the slots, the centre portion of the flame appearing between the lower tube and the chimney, gives a definite quantity of light.

The 10-candle Pentane Argand, which is the latest proposed standard, is the result of the combined efforts of Mr. A. Vernon Harcourt and Mr. Dibdin, and was recommended to Parliament in 1895 by "The Standards of Light Committee," as a trustworthy standard for official use in testing the illuminating power of the gas supplied by the London Gas Companies.

A description of Mr. Dibdin's apparatus, Fig. 157, is given in Section IX. of the appendix of the Committee's Report as follows:—

The apparatus used in producing this standard consists of two separate portions, viz., the burner and the carburettor.

The burner is a specially constructed tricurrent Argand burner; the annular steatite ring being perforated with 42 holes, each hole being 0·71 millimetre in diameter. The three air currents are: (1) The central current rising inside the steatite to the inner portion of the flame; (2) a current rising outside the steatite, and caused to impinge upon the flame by an inner metal perforated and incurved cone, the top of which is level with the top of the steatite. (3) An outer current rising on the outside of the above cone, and between

that cone and the glass chimney. The inner perforated cone is punctured with ten apertures, 0·25 inch in diameter, which are provided for the purpose of equalizing the two outer currents of air as may be required to suit the height of the flame.

The glass chimney is carried in the groove provided on the outer cone, which answers the purpose of a gallery; the dimensions of the chimney being 6 inches high and 1½ inches inside diameter.

FIG. 157. DIBDIN'S 10-CANDLE PENTANE ARGAND.

Measurements of Burner.

Number of holes	42	
Diameter of holes	0·71 mm.	= 0·028 ins.
Inside diameter of steatite	9·90 „	= 0·390 „
Outside diameter of steatite.	19·05 „	= 0·750 „
Diameter of inside of metal cone at top . .	23·62 „	= 0·930 „
Chimney, length	152·40 „	= 6·000 „
„ inside diameter	38·10 „	= 1·500 „
Height of cut-off	54·61 „	= 2·150 „

The centre of the flame to be immediately over the terminal of the photometer-bar.

The top of the flame should be maintained as nearly as possible at 3 inches above the steatite, this point being indicated by the wires crossing the blue glass screens carried on each side of the burner on the metal supports. The flame is steadied by the small air directing cone situated centrally beneath the steatite, the apex being 0·08 inch below the metal support carrying the steatite.

On the side of the burner to be presented to the photometer disc, a metal screen 8½ inches in height is placed and screwed securely to the base plate. The middle portion of this screen is cut away so as to leave above the top of the steatite burner an opening 2·15 inches in height and 1·4 inches in width, the lower portion of this opening being exactly level with the top of the steatite. The light emitted horizontally through this opening by the flame produced by the combustion of the gaseous mixture of atmospheric air and pentane, formed in the carburettor described below, is used as the standard of light. It is equal to the light emitted by 10 parliamentary sperm candles.

The lower portion of the screen has an opening 1 inch wide by 2·8 inches in height, to allow free access of air to the under portion of the burner.

The position of the burner in relation to the photometer disc is to be fixed by the burner fitting gas-tight into a faced joint attached to the photometer at the required point; and the burner is to be set at such a height that the centre of the illuminated disc and the bottom edge of the cut-off shall be in the same horizontal plane. The length of the connection between the burner and carburettor may be varied, but should not be more than 5 feet. The centre of the flame is to be immediately over the terminal point of the photometer-bar.

The carburettor for the 10-candle Pentane Argand consists of a circular vessel constructed of tinned plate, 203·2 mm. (8 inches) in diameter, and 50·8 mm. (2 inches) in depth, having a spiral division 25·4 mm. (1 inch) in width. This division is made by soldering a strip of metal, 4 ft. 6 in. in length and 2 inches wide, gas tight, to the under side of the top of the carburettor; so that when the top is fixed on, the bottom of the strip comes close to the bottom of the vessel, and is sealed by the pentane, so that the air has to pass over pentane for a distance of about 4 ft. 6 in. and becomes thoroughly saturated. At

the end of the spiral division, near the side of the carburettor, a bird fountain is fixed for charging the carburettor, and keeping it charged at a constant level with liquid pentane. The lower end of the liquid fountain tube is closed, and rests upon the bottom of the tank. Through the side of the tube, which is 0·4 inch (10·1 mm.) in diameter, 16 holes, 1 mm. in diameter, are bored close to the bottom, and through these the pentane enters the carburettor. At the inside of the inlet tube, 1 inch from the lower end, a small tube, 3 mm. in diameter and 20 mm. in length, is connected thereto and turned upwards. The fountain inlet tube is carried up through the top of the carburettor, and continued in the form of a bulb having a capacity of about 200 c.c. Stopcocks are provided at the top and bottom of the bulb, for convenience in filling with pentane; and the portion above the upper stopcock is opened out in a funnel shape for the same purpose. When the carburettor is being charged, the gas must be extinguished to avoid the risk of the vapour firing and causing an explosion.

The inlet for gas or air is at the side of the carburettor and at the terminal of the spiral division, the outlet being placed in the centre of the vessel so that the air or gas may travel over the liquid pentane throughout the whole length of the spiral division, and thus become fully charged with the volatile vapour of the pentane.

When using this standard the pentane must be visible in the fountain bulb.

Mr. A. Vernon Harcourt's new 10-candle pentane lamp, Fig. 158, (for the sale of which Alexander Wright and Co., Limited, have been appointed sole agents), embodies the latest and ripest ideas of what is required in a perfect standard of light, viz.: That it should be simple in construction, efficient in action, and easy of manipulation. In this instrument, besides other marked improvements in the direction of simplicity, the pentane is fed to the burner by gravitation from the vessel on the upper end, thus ensuring great regularity of flame, a matter, obviously, of the utmost importance in a light standard.

The inventor gives the following instructions for putting the lamp in action:—

The lamp, having been placed in the position it is to occupy, with the reservoir of pentane half full upon the bracket, is levelled by observing that the height of the pentane against the glass is the same on both sides. Its height is then adjusted so that the bottom of the

chimney-tube is at the same height above the bench or table as the centre of the disc or photoped. The distance between the top of the burner and the bottom of the chimney-tube is set at 47mm. (1·85 inches), and is accurately centred, by means of a cylindrical wooden block. To light the lamp, the two stopcocks of the reservoir are opened, and the india-rubber tube is alternately pressed and relaxed a few times, that pentane vapour may pass into it. The pinchcock, which has been closed, is then gradually opened, and the lamp is lit. The top of the flame should rise about an inch above the bottom of the chimney-tube. The light given by the flame below the chimney-tube is the same as long as the top of the flame, looked at horizontally through the talc window, is above the bottom of the window, and does not reach the crossbar. To put out the lamp, the stopcocks and pinchcock are closed. The original adjustments need only be repeated when the lamp has been moved. The small cone which is placed round the flame, to steady and screen it, has its opening turned in the direction in which the beam of light is to go. If the lamp-black coating should be rubbed off the inside of the cone, it must be renewed. The lamp should be lit a quarter of an hour before it is used, and the height of the flame adjusted from time to time by a small movement of the pinchcock.

FIG. 158. HARCOURT'S 10-CANDLE PENTANE BURNER.

JET PHOTOMETERS.

The three following instruments, which are each employed to determine the illuminating value of gas, though only approximately correct in their indications, are yet sufficiently trustworthy to render them useful and valuable auxiliaries to the more absolute method of testing already described.

Their great recommendations are their portability, and the ease and celerity with which the illuminating power can be ascertained by their aid.

Their action depends on the relation which the specific gravity of the gas bears to its illuminating power. The flame being kept at a given height, the pressure required, and therefore the rate of consumption, will vary according to the density of the gas and its consequent illuminating value.

The Jet Photometer.

Lowe's jet photometer, as improved by Sugg and Kirkham (Fig. 159), affords a ready means of ascertaining, by a momentary inspection,

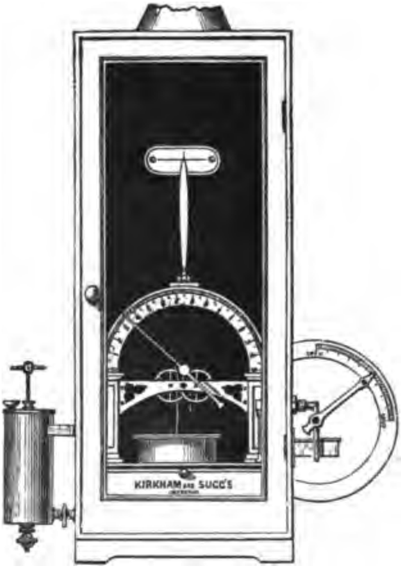


FIG. 159.

whether the gas being produced is uniform in quality. The apparatus consists of a King's gauge of delicate construction, with its semicircular scale indicating the pressure. A steatite jet having a fine orifice is fixed at the top of this, and the gas issuing therefrom, and being lighted, gives a flame which should be constantly maintained at 7 inches.

The scale shown in Fig. 160 is for gas of 14 to 19 candles illuminating power. The same scale is used for 20, 25, or 30 candle gas, but with a different jet, and a lesser consumption per hour, the gauge pointing to the place where the figure 16 stands, but with the number changed to 20, 25, or 30, conforming to the standard quality of the gas to be supplied according to the Special Act of Parliament.

The range of the jet is necessarily short. It is correct at the gauge point, but with a slightly increasing error on the numbers above and below—the error being against the gas in going up, and in favour of it in going down. This is due to variations in the pressure—increasing or diminishing—at the point of ignition. Within the degrees marked on the scale, however, this error is not important.

The gas-tap is shown on the right side of the instrument. The small cylinder on the left side is in communication with the water-cistern in the body of the gauge, and contains a compensator, which,

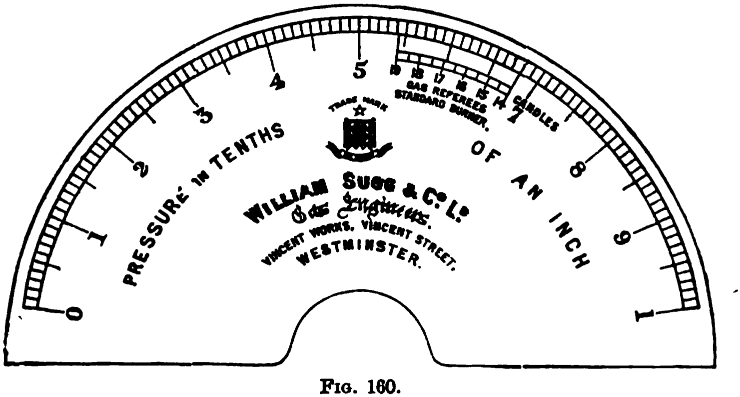


FIG. 160.

on being screwed up or down as required, adjusts the water-line, so that the pointer of the gauge stands at zero when the gas-tap is closed.

Sugg's Illuminating Power Meter.

This instrument is shown in Fig. 161, and, as the name indicates, is used for ascertaining the illuminating power of gas. The mode of putting it in operation is as follows:—Having filled it up to the water line scratched on the glass in the small box on the right side, connect it to the gas supply with a piece of metal tube. The inlet is a ground

union joint, fixed in the centre of the back of the instrument. Turn the lever so as to make the gas pass through the measuring-drum, and let it get rid of all the air, or other kind of gas in it. Light the burner and adjust the flame to 3 inches in height. Then, when the large hand arrives at 16, change the position of the lever, so as to make the gas pass to the burner without going through the measuring-drum. The large hand will then stop at 16. Wind up the clock by means of the *remontoir* on the top of the meter just in the rear of the dial ring. Start the clock by moving the slide which is on the left of the meter, close to the governor. Then, when the hand of the clock is passing any one of the divisions of the minute, change the position of the lever of the bye-pass, so as to make the gas pass through the meter. When the hand has made one complete revolution, stop the meter by means of the lever, in the manner before described, and read off the illuminating power. The minute clock should not be stopped either before or after the observation, unless it is desired to put the clock entirely at rest.

FIG. 161.

Thorp and Tasker's Jet Photometer.

This is an ingenious and handy instrument (Fig. 162), for enabling the illuminating value of the gas to be ascertained from inspection at any time and place. It is well understood that the quantity of gas passed in a given time will bear a proportion to the size of the orifice (this is the principle on which the aërorheometer is made—a useful instrument by the same inventors for indicating the quantity of gas consumed by different burners, &c.); and further that the gas-flame being maintained at a given height, the quantity of gas consumed, and the pressure, will vary as the illuminating power. A moveable or floating disc inside the glass tube regulates the size of the orifice, and its position in the tube, corresponding to the graduations of the scale at the side, indicates the illuminating value.

VARIATIONS IN THE ILLUMINATING POWER OF GAS.

Fig. 162.

Most gas managers, in the course of their experience, must have observed variations, sometimes considerable, in the illuminating power of their gas, for which they have been unable satisfactorily to account. These variations are unquestionably due, to a great extent, to changes of atmospheric pressure. When the pressure is augmented, the luminosity is increased, and *vice versâ*. To determine this point, Dr. Frankland instituted a series of important experiments, of which the following are the results:—

Pressure of Air in Inches of Mercury.	Observed Illuminating Power.
30·2	100·0
28·2	91·4
26·2	80·6
24·2	73·0
22·2	61·4
20·2	47·8
18·2	37·4
16·2	29·4
14·2	19·8
12·2	12·5
10·2	3·6

The diminution of luminosity follows a fixed and definite law, which may be thus expressed: The decrease in illuminating power is directly proportional to the decrease of atmospheric pressure. Of 100 units of light emitted by a gas-flame burning in air, 5·1 units are extinguished by each reduction of 1 mercurial inch of atmospheric pressure. On the other hand, if a lightless flame be made to burn under augmented pressure it becomes luminous. The chief cause of the difference is the increase in the volume, and therefore decrease of the density, of those heavy hydrocarbons to which the luminosity of a gas-flame is attributed when the atmospheric pressure is reduced, and *vice versâ*.

TABLE

Showing the Percentage of Loss of Light by Mixing Air with Coal Gas.

Per Cent. Air.	Loss of Light. Per Cent.	Per Cent. Air.	Loss of Light. Per Cent.
1	6	8	58
2	11	9	64
3	18	10	67
4	26	15	80
5	33	20	93
6	44	30	98
7	53	40	100

TABLE

Comparing (approximately) the Specific Gravity of Gas (Air being 1·000) *with the Illuminating Power in Standard Sperm Candles.*

No. of Cndls.		Spec. Grav.	No. of Cndls.		Spec. Grav.	No. of Cndls.		Spec. Grav.
10	equal to about	·380	20	equal to about	·506	30	equal to about	·678
11	”	·392	21	”	·522	31	”	·694
12	”	·405	22	”	·537	32	”	·708
13	”	·416	23	”	·550	33	”	·722
14	”	·430	24	”	·565	34	”	·738
15	”	·443	25	”	·585	35	”	·755
16	”	·455	26	”	·605	36	”	·775
17	”	·468	27	”	·625	37	”	·790
18	”	·482	28	”	·645			
19	”	·495	29	”	·662			

THE SPECIFIC GRAVITY OF GAS.

Specific Gravity a Test of Quality.

If coal gas is free from carbonic acid, sulphuretted hydrogen, and air, specific gravity is a proper test of quality ; the denser it is, the greater will be its illuminating power—increase in weight and light-giving property being due to the presence of a larger proportion of olefiant gas and the other richer and heavier hydrocarbons.

Ordinary Method of Determining the Specific Gravity.

The apparatus required in determining the specific gravity of gas are a thin glass globe of about 100 cubic inches capacity, with two stopcocks on opposite sides, a good air-pump, and a very delicate balance. The experimental room should also be furnished with a barometer, showing the atmospheric pressure, and thermometers indicating the temperature both of the air and gas. The method of manipulation is as follows :—

First.—Open the two stopcocks ; the globe will then be full of air at the atmospheric pressure and temperature. Carefully weigh the globe while in this state, and make a note of the weight.

Second.—Attach the globe by one of the stopcocks to the air-pump, close the other stopcock, and exhaust it as perfectly as possible. Having closed the stopcock, remove the globe and weigh it in its exhausted state. Suppose that it now weighs 31·5 grains less than before, then these 31·5 grains represent the weight of the air abstracted.

Third.—Now attach the globe either to an experimental gasholder or to a gas-pillar connected by a pipe to the main, and fill the globe with the gas. When full, remove it and weigh it a third time. Suppose that the weight is now 14·2 grains more than when in its exhausted state, then these 14·2 grains represent the weight of the contained gas. Then, as 31·5 (the weight of the air) is to 14·2 (the weight of the gas), so is 1·000 (the specific gravity of the air) to the specific gravity of the gas. Or divide the weight of the gas by the weight of the air, and the quotient is the specific gravity of the gas; thus—

$$\frac{14{\cdot}2}{31{\cdot}5} = {\cdot}450, \text{ specific gravity of the gas compared with air as unity, or } 1{\cdot}000.$$

Dr. Letheby's Method of Determining the Specific Gravity.

With Dr. Letheby's apparatus (Fig. 163) the use of the air-pump is dispensed with. It consists of a similar glass globe about six inches in diameter, furnished with two stopcocks, to one of which is attached a glass tube half an inch in diameter and 7 inches long, fitted with a jet for burning the gas, and having a thermometer inside of the tube to indicate the temperature. The other stopcock can be attached by a suitable nozzle to a gas-pillar, and in practice the gas is kept flowing through the apparatus, being consumed from the jet at the upper end. The exact weight of the globe when full of air at mean temperature and pressure is engraved upon it; and a counterpoise weight is provided, exactly equal to the weight of the globe when exhausted.

Fig. 163.

When it is required to determine the specific gravity of the gas, the lower or supply-cock is first closed, and the upper one immediately afterwards. This order is necessary to be observed in the shutting of the cocks, because if the

upper one were first closed, the gas within the globe would be at the pressure of the gas within the main, instead of that of the atmosphere. The globe is then placed in the balance, and a sufficient number of grains and fractional parts added to the pan containing the counterpoise weight to equalise the beam. Suppose that it takes fifteen grains, then these represent the weight of the gas, and say that the globeful of air weighs 85 grains, then—

$$\frac{15}{85} = \cdot 429, \text{ the specific gravity of the gas.}$$

But it is necessary in making such observations to correct the volume of gas to mean temperature and pressure, and to allow for the moisture present in all aëriform bodies in contact with water. To these points the observations which follow apply.

CORRECTIONS FOR TEMPERATURE, BAROMETRIC PRESSURE, AND MOISTURE.

Owing to the contraction and expansion which take place in the bulk of all aëriform bodies, due to the variations in atmospheric temperature and pressure, it is necessary, when estimating and comparing their volume, to adopt one common temperature and barometric pressure as the standard. The mean temperature of 60° Fahr. and 30 inches of mercury have been adopted as the most convenient, and to this standard their volume is accordingly reduced. For example:

Correction for Temperature.—All aëriform bodies expand 1-491·4th part of their volume at 32° Fahr. for every degree of increase of temperature (1-273rd of the volume of the gas at 0° Centigrade for each degree of the same scale). Now suppose it is required to ascertain what volume 1000 cubic feet of gas at 68° will occupy at 60° the mean temperature. We know by the above-mentioned law that a quantity of gas which at 32° is 491·4 parts, will at 60° become 519·4 (60-32=28+491·4=519·4) and at 68°, 527·4 (68-32=36+491·4=527·4), then—

$$\frac{1000 \times 519 \cdot 4}{527 \cdot 4} = 984 \cdot 83 \text{ cubic feet.}$$

Or, again, if it is required to know the volume which 1000 cubic feet of gas at 56° will occupy at 60°, then—

$$\frac{1000 \times 519 \cdot 4}{515 \cdot 4} = 1007 \cdot 76 \text{ cubic feet.}$$

Correction for Pressure.—The amount of decrease or increase in volume is inversely as the pressure. To ascertain what volume 1000 cubic feet of gas at 28·5 inches will occupy when the mercury stands at 30 inches, the mean barometric pressure, then—

$$\frac{1000 \times 28 \cdot 5}{30} = 950 \text{ cubic feet.}$$

Or, again, if it is desired to ascertain the volume which 1000 cubic feet of gas at 30·6 inches will occupy at 30 inches, then—

$$\frac{1000 \times 30 \cdot 6}{30} = 1020 \text{ cubic feet.}$$

Or,

Correcting at Once for Temperature and Pressure.—Suppose it is required to ascertain what volume 1000 cubic feet of gas at 72° temperature and 29·8 inches pressure will occupy at standard temperature and pressure, then—

$$1000 \times \frac{519 \cdot 4}{531 \cdot 4} \times \frac{29 \cdot 8}{30} = 970 \cdot 90 \text{ cubic feet.}$$

Correction for Moisture.—It has been proved by experiment that one cubic inch of permanent aqueous vapour at the mean temperature of 60°, and the mean pressure of 30 inches, weighs ·1929 grains; and the following Table, founded on the researches of Dalton and Ure, and given by Faraday in his "Chemical Manipulation," shows the proportion by volume of aqueous vapour existing in any gas standing over or in contact with water, at the different temperatures indicated, and at a mean barometric pressure of 30 inches.

Temp. Deg. Fahr.	Proportion of Vapour in One Volume of Gas.	Temp. Deg. Fahr.	Proportion of Vapour in One Volume of Gas.	Temp. Deg. Fahr.	Proportion of Vapour in One Volume of Gas.
40	·00933	54	·01533	68	·02406
41	·00973	55	·01586	69	·02483
42	·01013	56	·01640	70	·02566
43	·01053	57	·01693	71	·02653
44	·01093	58	·01753	72	·02740
45	·01133	59	·01810	73	·02830
46	·01173	60	·01866	74	·02923
47	·01213	61	·01923	75	·03020
48	·01253	62	·01980	76	·03120
49	·01293	63	·02060	77	·03220
50	·01333	64	·02120	78	·03323
51	·01380	65	·02190	79	·03423
52	·01426	66	·02260	80	·03533
53	·01480	67	·02330	—	—

To determine by means of this table the quantity of aqueous vapour present, it is necessary to multiply the volume of the gas by the tabular number corresponding to the temperature, thus:—Suppose 100 cubic inches of gas weigh 16 grains at the temperature of 72°, and at mean barometric pressure, then, according to the table, the volume of aqueous vapour present is—

$$100 \times \cdot 02740 = 2\cdot 74 \text{ cubic inches.}$$

This corrected to mean temperature will be

$$2\cdot 74 \times \frac{491\cdot 4+28}{491\cdot 4+40} = 2\cdot 678 \text{ cubic inches.}$$

Now, with respect to the volume of the gas, 100 cubic inches at 72° are equal to—

$$100 \times \frac{491\cdot 4+28}{491\cdot 4+40} = 97\cdot 7 \text{ cubic inches at a temperature of } 60°$$

Hence $97\cdot 7 - 2\cdot 678 = 95\cdot 022$ cubic inches, the volume of dry gas at mean temperature and pressure.

To arrive at the weight of the volume of dry gas, the volume of aqueous vapour must be multiplied by ·1929 grains, the weight of a cubic inch of permanent aqueous vapour, as before stated, and the product deducted from the total weight of 16 grains; thus—

$$16 - (2\cdot 678 \times \cdot 1929) = 15\cdot 483 \text{ grains.}$$

Then for the weight of 100 cubic inches of dry gas we have—

$$\frac{15\cdot 483 \times 100}{95\cdot 022} = 16\cdot 293 \text{ grains.}$$

And as 100 cubic inches of air at mean temperature and pressure weigh 31 grains, we have—

$$\frac{16\cdot 293}{31} = \cdot 525, \text{ as the specific gravity of the gas.}$$

If, instead of making the correction for moisture, it is preferred to dry the gas as it passes into the globe, this may be done by causing it to flow through a glass tube, half an inch in diameter and about 18 to 20 inches long, containing pieces of dry calcium chloride; that substance having a strong affinity for moisture. Before using, the chloride of calcium should be fused in an earthenware crucible at a low temperature, then poured on a clean stone surface, and as soon as cold, broken in pieces and put in the tube. The gas in passing through the tube to fill the globe should be made to travel slowly; about 15 minutes being the usual time allowed.

Wright's Method of Determining the Specific Gravity.

For ascertaining the specific gravity of gas, Mr. Wright used a light balloon (Fig. 164), capable of containing one cubic foot or 1728 cubic inches.

His directions for performing the experiment are as follows :—

Fig. 164.

Expel the air from the balloon by folding it in the form in which it is first received, ascertain the weight of the balloon and car, fill the balloon with gas, insert the stopper, and put as many grains * in the car as will balance it in the air; add the number of grains which it carries to the weight of the balloon, and deduct the amount from the tabular number corresponding to the degree of temperature indicated by the thermometer, and the pressure indicated by the barometer (pp. 314-15); divide the result by the tabular number due to the temperature and pressure of the gas (to ascertain which, allow the gas to blow upon the bulb of the thermometer until the mercury is stationary), and the first three figures are the specific gravity.

Example I.

Temperature of the air	70°	Tabular number, 924.
Barometer	28·5 in.	
Temperature of the gas	56°	Tabular number, 959.
Barometer always the same as air .	28·5 in.	

Weight of balloon and grains in car, 560.

Then—

$$\frac{924-560}{959} = \cdot 879, \text{ the specific gravity.}$$

Example II.

Temperature of the air . . .	40°	Tabular number, 1067.
Barometer	30·5 in.	
Temperature of the gas . . .	62°	Tabular number, 1012.
Barometer always the same as air	30·5 in.	

Weight of balloon and grains in car, 560.

* The weights used are not troy grains, 100 of them being equal to 58·56 troy grains; they are each equal to 1·728 cubic inches of air, when the barometer is at 30 inches, and the thermometer at 60°.

Then—

$$\frac{1067 - 560}{1012} = \cdot 501, \text{ the specific gravity.}$$

Lux's Specific Gravity Apparatus.

The gas-balance, shown in Fig. 165, for determining the specific gravity of illuminating gas, is the invention of Mr. Frederick Lux.

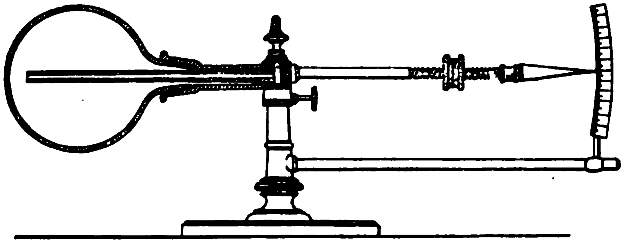


FIG. 165.

It is constructed on the principle of the common lever-balance, with a curved scale attached by means of a coupling-rod to the standard. The scale is graduated from 0 to 1; and the tongue or pointer, moving in close proximity thereto, enables the operator to take a direct reading of the specific gravity of the gas under examination.

Instead of consuming the gas through the vertical tube, a pipe can be arranged to convey the gas to the photometer for the purpose of testing its illuminating power.

To Find the Weight in Pounds of any Quantity of Gas at 60° Fahr. and 30 in. Bar., the Specific Gravity being known.

RULE.—Multiply the quantity in feet by the specific gravity, and the product by ·07497 (weight of a cubic foot of air), and the answer will be the weight of gas in lbs. avoirdupois.

EXAMPLE.—What is the weight of 9400 cubic feet of gas, its specific gravity being ·480?

$$9400 \times \cdot 480 \times \cdot 07497 = 338 \cdot 26 \text{ lbs. of gas.}$$

TABLE.

WEIGHT OF 1000 CUBIC FEET OF COAL GAS OF DIFFERENT SPECIFIC GRAVITIES AT 60° FAHR. AND 30 INCHES BAR., SATURATED WITH MOISTURE.

Specific Gravity. Air 1·000	Weight per 1000 Cubic Feet. lbs.	Specific Gravity. Air 1·000	Weight per 1000 Cubic Feet. lbs.	Specific Gravity. Air 1·000	Weight per 1000 Cubic Feet. lbs.
·380	28·489	·470	35·235	·560	41·983
·385	28·863	·475	35·610	·565	42·358
·390	29·238	·480	35·985	·570	42·732
·395	29·613	·485	36·360	·575	43·107
·400	29·988	·490	36·735	·580	43·482
·405	30·363	·495	37·110	·585	43·857
·410	30·738	·500	37·485	·590	44·232
·415	31·113	·505	37·860	·595	44·607
·420	31·487	·510	38·235	·600	44·982
·425	31·862	·515	38·610	·605	45·357
·430	32·237	·520	38·984	·610	45·732
·435	32·612	·525	39·359	·615	46·107
·440	32·987	·530	39·734	·620	46·481
·445	33·362	·535	40·109	·625	46·856
·450	33·737	·540	40·484	·630	47·231
·455	34·111	·545	40·859	·635	47·606
·460	34·486	·550	41·234	·640	47·981
·465	34·861	·555	41·608	·645	48·356

TABLE OF VARIOUS GASES,

THEIR DENSITY, SPECIFIC GRAVITY, AND WEIGHT, DRY AND SATURATED WITH MOISTURE, AT THE STANDARD BAROMETRIC PRESSURE OF 30 INCHES.

Name.	Symbol.	Density.	Specific Gravity. Air equal 1·000.	Weight of 1 Cubic Foot in Grains. At 32° F. Dry.	Weight of 1 Cubic Foot in Grains. At 60° F. Saturated.	Cubic Feet equal to 1lb. av'rdupois. At 32° F. Dry.	Cubic Feet equal to 1lb. av'rdupois. At 60° F Satrtd.
Hydrogen	H	1·000	·0693	39·15	36·39	178·80	192·36
Light Carburetted Hydrogen	CH_4	7·985	·554	312·61	290·57	22·39	24·09
Ammonia	NH_3	8·510	·590	333·17	309·68	21·01	22·60
Acetylene	C_2H_2	12·970	·899	507·58	471·99	13·79	14·83
Carbonic Oxide	CO	13·965	·968	546·73	508·19	12·80	13·77
Olefiant Gas	C_2H_4	13·970	·969	546·93	508·37	12·80	13·77
Nitrogen	N	14·020	·9721	548·88	510·19	12·75	13·72
Air		14·422	1·000	564·62	524·82	12·40	13·34
Nitric Oxide	NO	14·990	1·039	586·86	545·49	11·93	12·83
Oxygen	O	15·960	1·1066	624·83	580·78	11·20	12·05
Sulphuretted Hydrogen	H_2S	16·990	1·178	665·16	618·27	10·52	11·32
Carbonic Acid	CO_2	21·945	1·522	859·15	798·58	8·15	8·76
Nitrous Oxide	N_2O	22·000	1·525	861·30	800·58	8·13	8·74
Sulphurous Acid	SO_2	31·950	2·257	1,250·84	1,162·66	5·59	6·02
Chlorine	Cl	35·370	2·452	1,384·74	1,287·11	5·06	5·44
Bisulphide of Carbon	CS_2	37·965	2·632	1,486·33	1,381·55	4·71	5·07

THE ENRICHMENT OF COAL GAS.

When a higher illuminating power than that yielded by the gas produced from ordinary bituminous coal is desired, some method of enrichment is resorted to.

Cannel was formerly the only medium employed for this purpose, and it is the best and simplest, inasmuch as the gas from it is a more regular and durable enricher than any other, and does not require any special and separate apparatus for its production, but of recent years other methods of enrichment by means of oil of different kinds have been introduced, owing to their being less costly.

It does not follow, however, that cannel is or will be entirely abandoned for enrichment purposes. All depends upon the price, and there are already signs that a return to its more general use may result from the increased market value of its rivals.

Gas enrichment is of less pressing concern to-day than it was at one time, because the principles of economical lighting are now better understood and more widely applied, resulting in the introduction of improved burners, and the better regulation of the pressure at or near to the point of consumption.

The incandescent gas-light, also, has shown how a vastly increased illuminating power may be obtained without resorting to enrichment, with, at the same time, a striking economy in gas consumption.

The chief advantage derived from enrichment is the assistance it lends towards preventing the deposit of naphthalene, the richer gas tending to keep this hydrocarbon suspended within it in the gaseous form.

The following is a résumé of the various enriching methods employed:

The Peebles Process consists in cracking or decomposing oil in iron retorts at a temperature of 1750° Fahr., and washing the resultant gas by the fresh oil, which is afterwards decomposed in a similar manner. Blue oil, having a specific gravity of ·85, is generally used. Its illuminating value as an enriching agent is about 90 candles per 5 cubic feet of the gas. The yield of coke is 5½ cwt. to the ton.

The Maxim-Clark System is a method of carburetting by means of gasoline volatilized in a copper retort heated by steam. The volatilized gasoline passes into a small holder traversed also by the gas to be enriched. One gallon of gasoline, having a specific gravity of ·68, suffices to raise 8000 cubic feet of 15 to 17 candle gas by one candle.

The Whessoe-Munich Method of enrichment is by means of benzol. This is volatilized in a vessel heated by steam, and fitted with ribbed trays covered with cloth, on to which the benzol drops. It is claimed as one of the advantages of this system that it is only necessary to pass a portion of the coal gas through the carburettor, and that such portion, being enriched, acts as an enricher for the rest. The quantity of benzol required to enrich 1000 cubic feet of gas one candle is 8 ounces.

The Dvorkovitz System enriches by means of solar distillate oil, specific gravity ·886. This is cracked or decomposed in iron retorts heated to a bright red, and the gas so produced, mixing in the proportion of 8 per cent. with ordinary coal gas of 15 to 16 candles value, raises the illuminating power about 1½ to 2 candles. The inventor claims a high value for the residual tar and oil.

Carburetted Water Gas.—The plant here is used both for gas making and gas enriching*. It consists of three vessels or shells, called the generator, the carburettor, and the superheater. The gas is made by admitting steam at about 100 lbs. pressure through a bed of incandescent coke. The steam being decomposed into its constituent gases oxygen and hydrogen, the resultant oxygen combines with the carbon of the coke forming carbonic acid, which, rising through the higher layers of incandescent coke, is reduced to carbonic oxide, and this mixing with the hydrogen forms what is called "water gas." This is non-luminous, and is afterwards enriched in the carburettor with oil, which imparts to the gas its light-giving properties. The gas thus enriched is passed through the superheater to "fix" the oil vapours.

The Dinsmore System of enriching with the hydrocarbons present in the tar has already been referred to, page 54.

* Gas is, of course, produced in all the other processes, but this is a gas producer on a large scale.

PUBLIC ILLUMINATIONS.

In provincial towns the Gas Manager is usually called upon to arrange and superintend the illuminations that are given to celebrate any great national or local event. On such occasions the following particulars will be found useful:—

Mode of Supply and Price of Gas.—Illumination devices are generally supplied with gas direct from the main, without the intervention of a meter to register the consumption. Where the illuminations are anything like universal, the fixing of meters is altogether impracticable.

Taking the consumption of each jet * to be at the rate of one cubic foot of gas per hour, which is a fair average, including loss by leakage and trial lighting, the following will be the rate of charge according to the price per 1000 cubic feet:—

At per 1000.			At per 1000.		
6s. 6d.	·078	of 1d. per jet* per hour.	4s. 2d.	·050	of 1d. per jet* per hour.
6 5	·077	„ „ „	4 1	·049	„ „ „
6 4	·076	„ „ „	4 0	·048	„ „ „
6 3	·075	„ „ „	3 11	·047	„ „ „
6 2	·074	„ „ „	3 10	·046	„ „ „
6 1	·073	„ „ „	3 9	·045	„ „ „
6 0	·072	„ „ „	3 8	·044	„ „ „
5 11	·071	„ „ „	3 7	·043	„ „ „
5 10	·070	„ „ „	3 6	·042	„ „ „
5 9	·069	„ „ „	3 5	·041	„ „ „
5 8	·068	„ „ „	3 4	·040	„ „ „
5 7	·067	„ „ „	3 3	·039	„ „ „
5 6	·066	„ „ „	3 2	·038	„ „ „
5 5	·065	„ „ „	3 1	·037	„ „ „
5 4	·064	„ „ „	3 0	·036	„ „ „
5 3	·063	„ „ „	2 11	·035	„ „ „
5 2	·062	„ „ „	2 10	·034	„ „ „
5 1	·061	„ „ „	2 9	·033	„ „ „
5 0	·060	„ „ „	2 8	·032	„ „ „
4 11	·059	„ „ „	2 7	·031	„ „ „
4 10	·058	„ „ „	2 6	·030	„ „ „
4 9	·057	„ „ „	2 5	·029	„ „ „
4 8	·056	„ „ „	2 4	·028	„ „ „
4 7	·055	„ „ „	2 3	·027	„ „ „
4 6	·054	„ „ „	2 2	·026	„ „ „
4 5	·053	„ „ „	2 1	·025	„ „ „
4 4	·052	„ „ „	2 0	·024	„ „ „
4 3	·051	„ „ „			

* By the term "jet," as here used, is meant the small gas-flame at each hole drilled or punched in the pipes forming the different devices.

When the ordinary No. 1, 2, and 3 fish-tail burners are employed, the consumption may be reckoned at the rate of 3, 4, and 5 cubic feet per hour each respectively, and charged accordingly.

It is proper to stipulate that no illumination should amount to less than 50s.

Service or Supply Pipes.—It is the usual rule for the Gas Authorities to convey at their own cost a service-pipe from the main, and from 8 to 12 feet up the front of the building to be illuminated, provided the whole length of pipe required does not exceed 36 feet. A charge is made for any additional length. The expense of fixing the devices in their position is also charged. To the end of the pipe in front of the building a stopcock is attached for shutting off or regulating the supply of gas.

Care should be taken to have the pipes of ample capacity, otherwise the illumination will be poor and ineffective.

When the building to be illuminated is large, it is advisable to run up a service-pipe at each end, and one in the centre, connecting them together in the front; each pipe, of course, having a distinct connection with the main in the street.

The service-pipes should be laid with a slight fall to the main; and the use of all abrupt angles—such as square elbows—should be avoided, bends being employed instead.

The service-pipes are temporary only, being lent by the Gas Authorities, and are removed by them when the illuminations are over.

Devices.—The devices are paid for by the private inhabitants, or the Local Authorities, or by both, as the case may be.

They may consist of—

Initial and other letters, single-lined—thus, A—and double-lined—thus, A

Mottoes—straight, curved, or circular.

Lanterns with coloured Devices.

Laurel Scrolls.

Garlands.

Festoons.

True Lovers' Knots.

Stars of various kinds.

Mitres.

Crescents.

Crosses.

Plumes, as Prince of Wales' Feathers.

Aureoles.
Crowns.
Shields.
Anchors.
Masonic Emblems.
Heraldic Crests.
Corporation Arms.
Other Devices suitable to the particular occasion.

The devices are made by the manufacturers of gas-fittings, wrought-iron tubing, and others, and are supplied to Gas Authorities and the Trade at about the following prices :—

Single-lined Letters, in Iron or Copper, fitted with Strong Union Couplings.

Length of Letter.	Size of Inlet.	Price.
18 inches	⅜ths inch bore	11s. 0d. each.
24 "	⅜ "	12 6 "
30 "	⅜ "	13 6 "
36 "	⅜ "	15 0 "
42 "	½ "	18 0 "
48 "	½ "	21 0 "
54 "	¾ "	25 0 "
60 "	¾ "	30 0 "

Double-lined Letters, in Iron or Copper, fitted with Strong Union Couplings.

Length of Letter.	Size of Inlet.	Price.
18 inches	⅜ths inch bore	12s. 6d. each.
24 "	⅜ "	15 0 "
30 "	½ "	17 6 "
36 "	½ "	20 0 "
42 "	¾ "	24 0 "
48 "	¾ "	28 0 "
54 "	1 "	33 0 "
60 "	1 "	40 0 "

Brunswick Stars and Stars with Eight points, Made of Wrought-Iron Welded Pipe, and fitted with Strong Union Couplings.

Diameter.	Size of Inlet.	Price with Star Centre. £ s. d.	Price with Shield Centre. £ s. d.	Price with Plume Centre. £ s. d.
3 feet	1 inch bore	2 0 0	2 2 0	2 17 0
4 "	1¼ "	2 12 0	2 15 0	3 10 0
5 "	1¼ "	3 6 6	3 10 0	4 5 0
6 "	1¼ "	4 15 0	5 0 0	5 15 0
7 "	1½ "	6 3 6	6 10 0	7 5 0
8 "	2 "	7 7 0	7 15 0	8 10 0

Crowns and plumes cost about one-third more than Stars.

Scrolls, garlands, heraldic crests, and other devices, at prices varying according to the elaboration of the design.

Wrought-iron pipes, drilled, and with star jets inserted, are supplied at about the ordinary list price.

The devices may be "home-made," and if so will be less expensive; but unless constructed by skilled and tasteful workmen, they will present a scraggy, irregular appearance when lighted up.

Illuminated Borders.—A very pretty effect, easily managed, and one that gives a rich fulness to the central illumination of a building, is obtained by running wrought-iron tubing along the principal angles, with holes drilled in the tube at distances about 6 inches apart, and having small jets or star burners inserted. The burners may be placed wider apart, and globes made use of. These prevent the lights from being extinguished by the wind, and also heighten the general effect. In this case a short piece of brass tube, with elbow-socket and gallery, must be inserted. Globes ground all over, or white opal globes, or white and coloured globes arranged alternately, show to the best advantage.

Coloured Fires.—A display of coloured fires, at intervals, from prominent points of elevation, adds greatly to the effect of an illumination.

The following are some excellent recipes for their production:—

Lilac Fire.

		Oz.	Drms.
Chlorate of potash	49 parts, or	7	18
Sulphur	25 ,,	4	0
Chalk	20 ,,	3	3
Black oxide of copper	6 ,,	1	0

This composition weighs 1 lb., and costs 2s. 3d.

Purple Fire.

		Oz.	Drms.
Chlorate of potash	43 parts, or	6	14
Nitrate of potash (saltpetre)	22½ ,,	3	10
Sulphur	22½ ,,	3	10
Black oxide of copper	10 ,,	1	9
Black sulphide of mercury (Ethiop's mineral)	2 ,,	0	5

Weight, 1 lb.; cost, 2s. 3d.

Yellow Fire.

		Oz.	Drms.
Nitrate of soda	75 parts, or	12	0
Sulphur	19 ,,	3	1
Charcoal or lamp black	6 ,,	0	15

Weight, 1 lb.; cost, 1s. 6d.

Blue or Bengal Fire.

		Oz.	Drms.
Dry nitrate of potash	6 parts, or	10	10½
Sulphur	2 „	3	9½
Tersulphide of antimony	1 „	1	12

Weight, 1 lb.; cost, 1s.

Or

		Oz.	Drms.
Ammonic sulphate of copper	8 parts, or	8	8
Chlorate of potash	6 „	6	7
Shellac	1 „	1	1

Weight, 1 lb.; cost, 2s. 3d.

Green Fire.

		Oz.	Drms.
Nitrate of baryta	77 parts, or	12	5
Sulphur	13 „	2	1
Chlorate of potash	5 „	0	13
Charcoal or lamp black	3 „	0	8
Metallic arsenic	2 „	0	5

Weight, 1 lb.; cost, 1s. 6d.

Or

		Oz.	Drms.
Nitrate of baryta	9 parts, or	10	10
Shellac	3 „	3	9
Chlorate of potash	1½ „	1	13

Weight, 1 lb.; cost, 1s. 6d.

Crimson Fire.

		Oz.	Drms.
Nitrate of strontia	80 parts, or	10	0
Sulphur	22½ „	2	14
Chlorate of potash	20 „	2	8
Charcoal or lamp black	5 „	0	10

Weight, 1 lb.; cost, 1s. 6d.

Red Fire.

		Oz.	Drms.
Nitrate of strontia	40 parts, or	10	0
Sulphur	13 „	3	2
Chlorate of potash	5 „	1	3
Charcoal or lamp black	3 „	0	11
Sulphide of antimony	4 „	1	0

Weight, 1 lb.; cost, 1s. 6d.

Or

		Oz.	Drms.
Nitrate of strontia	9 parts, or	10	10
Shellac	3 „	3	9
Chlorate of potash	1½ „	1	13

Weight, 1 lb.; cost, 1s. 6d.

White Indian Fire.

		Oz.	Drms.
Nitrate of potash	24 parts, or	11	10
Sulphur	7 ,,	8	6
Sulphide of arsenic (realgar)	2 ,,	1	0

Weight, 1 lb.; cost, 1s.

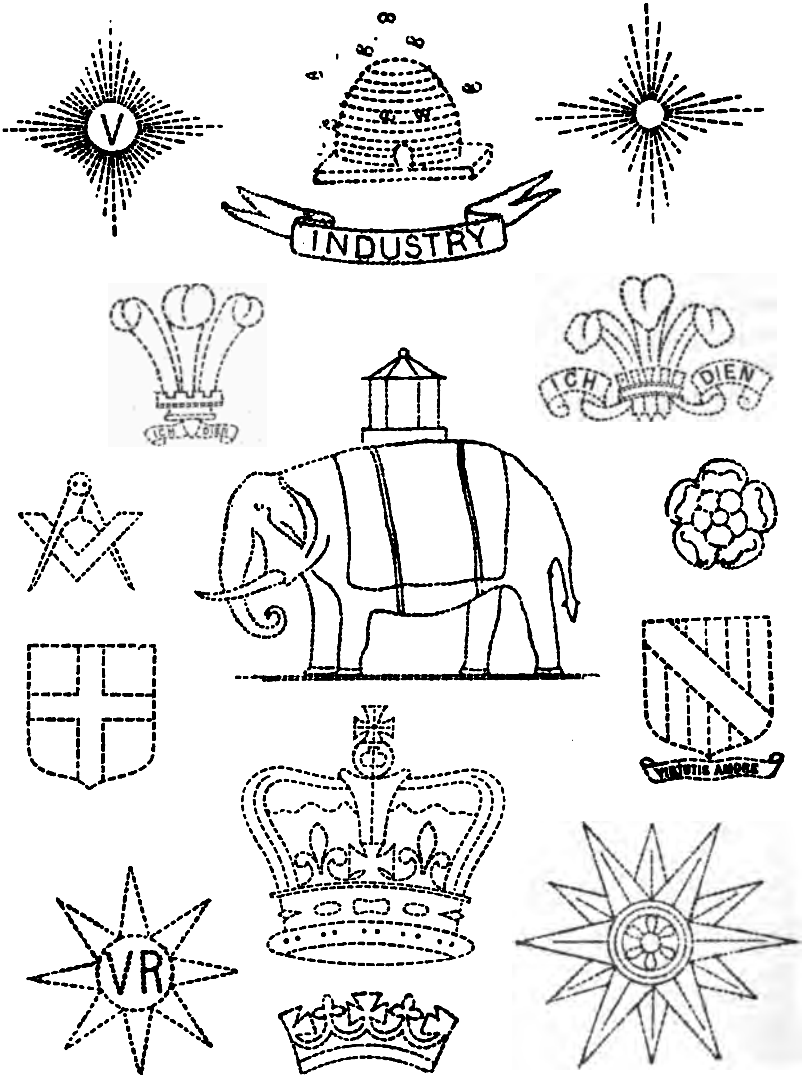
In no case should the chlorate of potash be ground along with the sulphur, as ignition, caused by the friction, might ensue.

The ingredients should be reduced to the finest powder (excepting the shellac, which should only be beaten into small fragments) by bruising them in a mortar made of hard wood, the chlorate of potash being ground separately. They should then be intimately mixed together, by passing them three or four times through a hair sieve. When mixed, keep the material in a close-stoppered bottle, to prevent spontaneous combustion. *All the ingredients must be perfectly dry to insure success.*

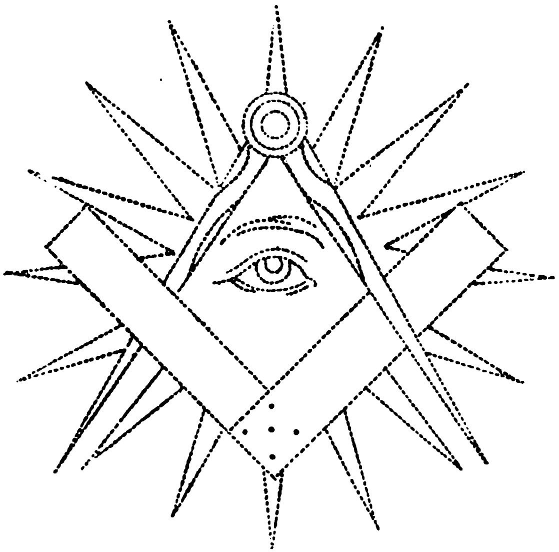
The mixtures are best fired in hemispherical dishes, or ladles made of beaten iron, about 5 inches diameter and 2½ inches deep in the centre. The fumes arising from the different fires should be avoided.

A pound in weight of any of the mixtures is sufficient for a fire (though any quantity may be used); and the cost varies from 1s. to 2s. 3d. each. The ingredients can be obtained from almost any chemist and druggist.

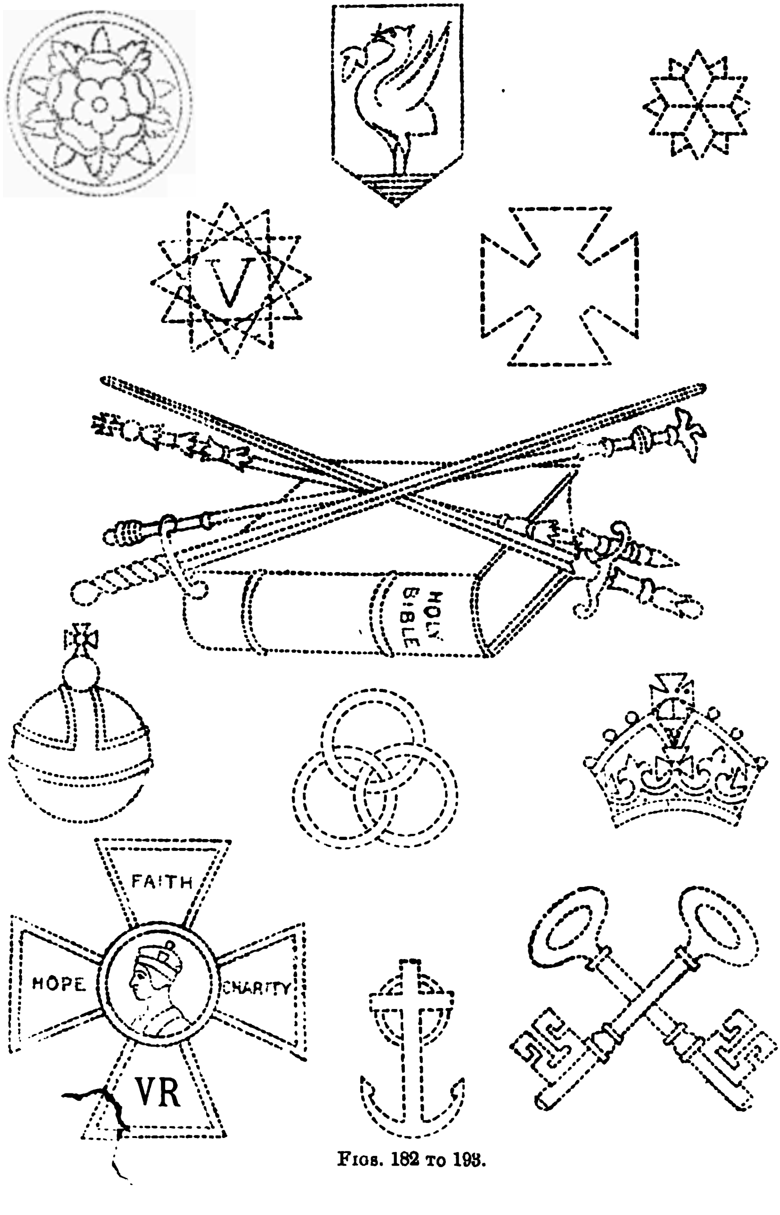
ILLUMINATION DEVICES.



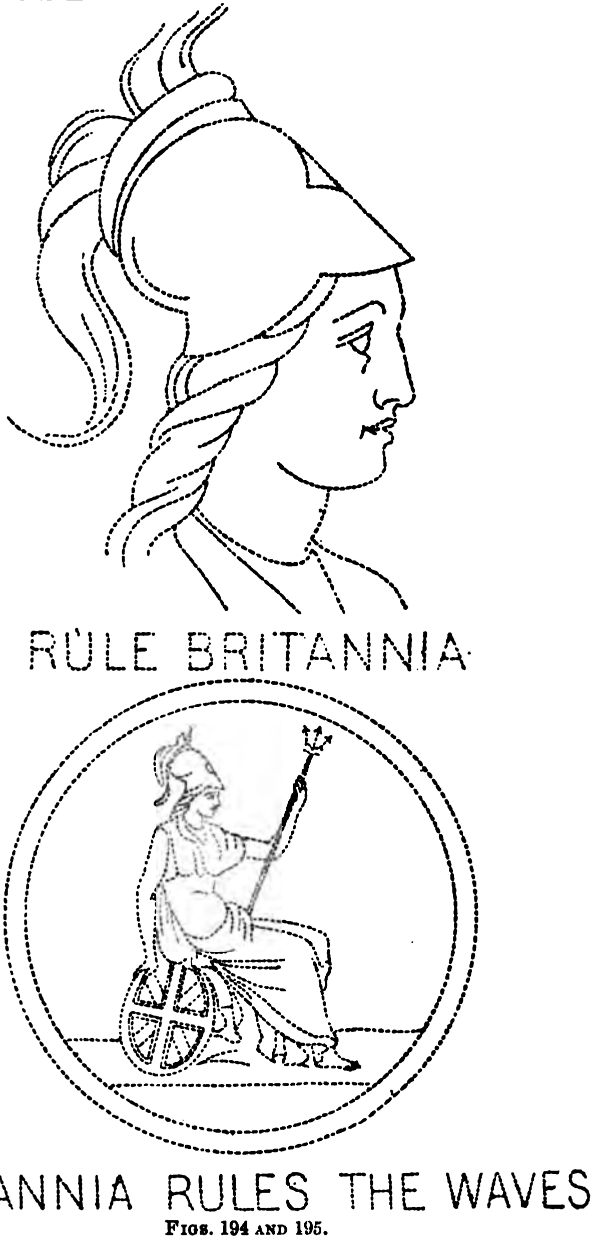
FIGS. 166 TO 179.



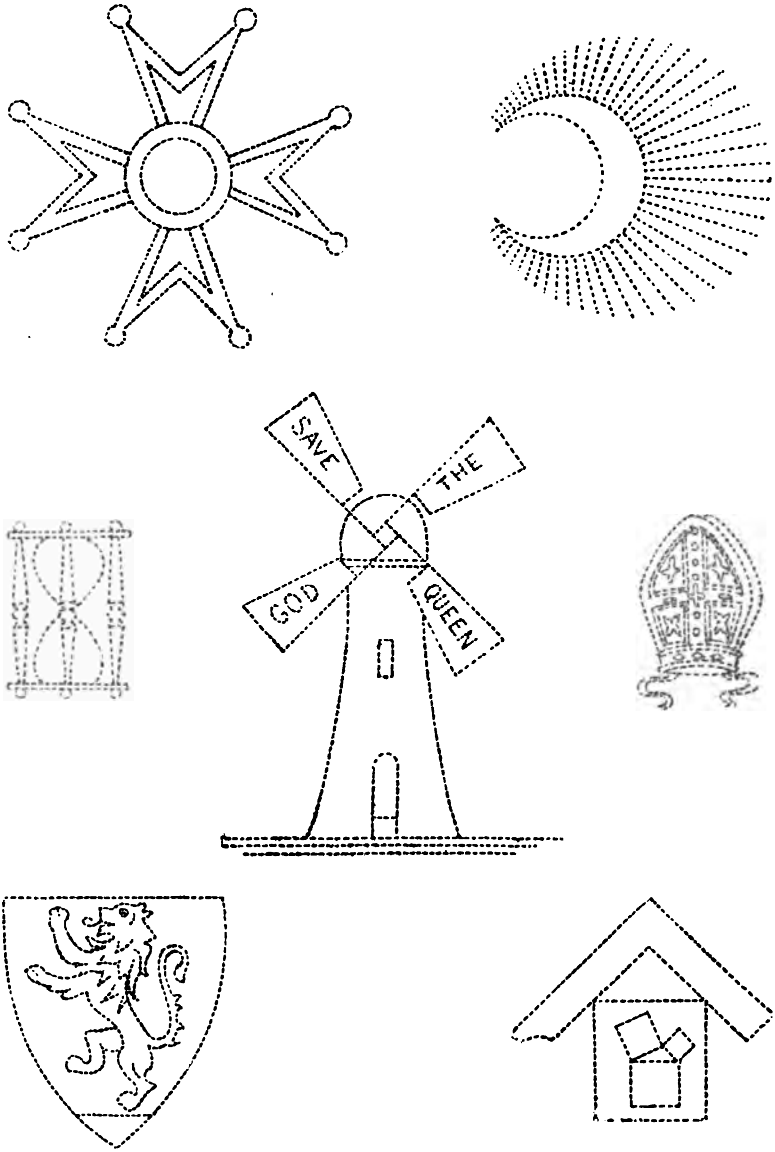
FIGS. 180 AND 181.



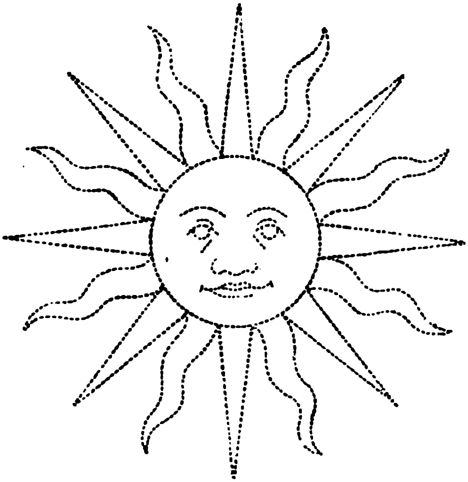
Figs. 182 to 193.



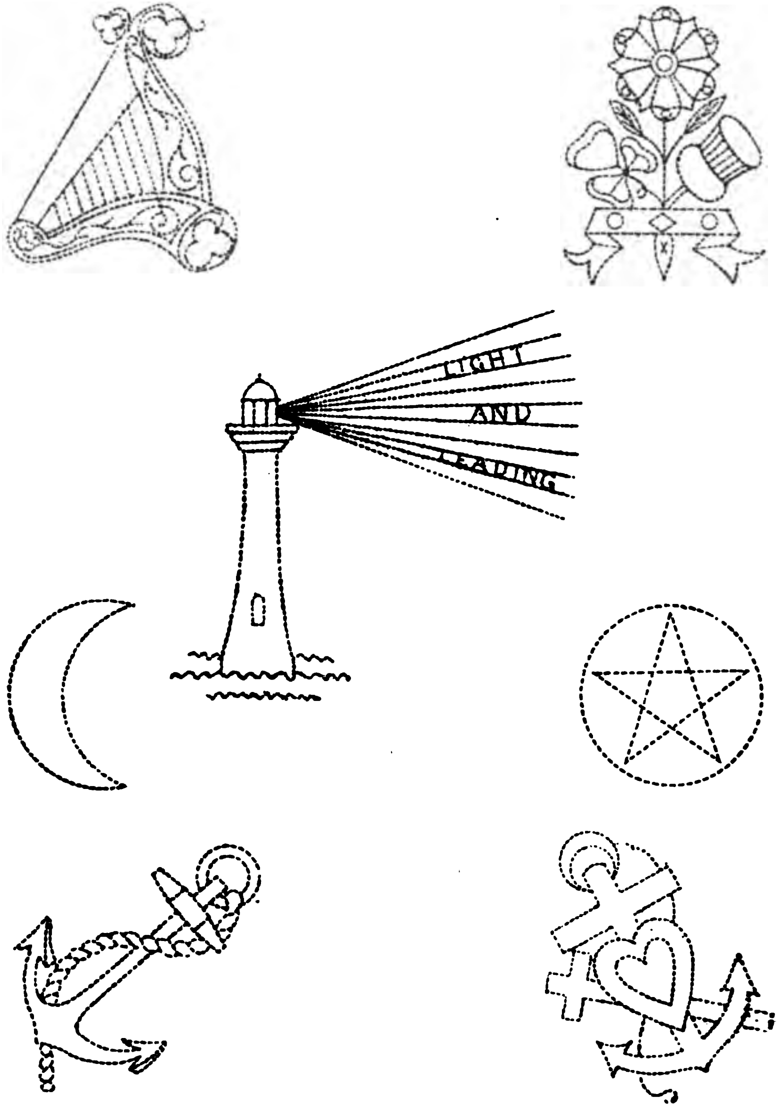
FIGS. 194 AND 195.



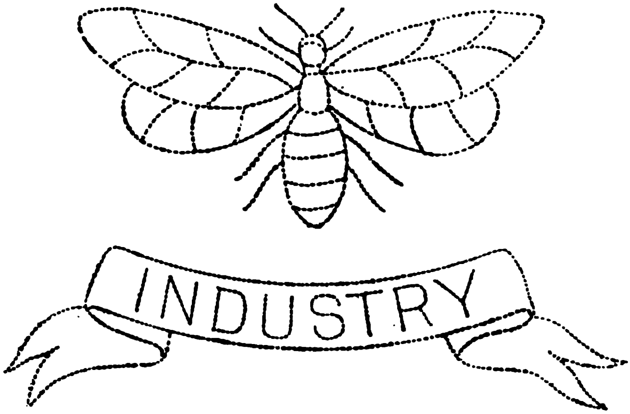
Figs. 196 to 202.



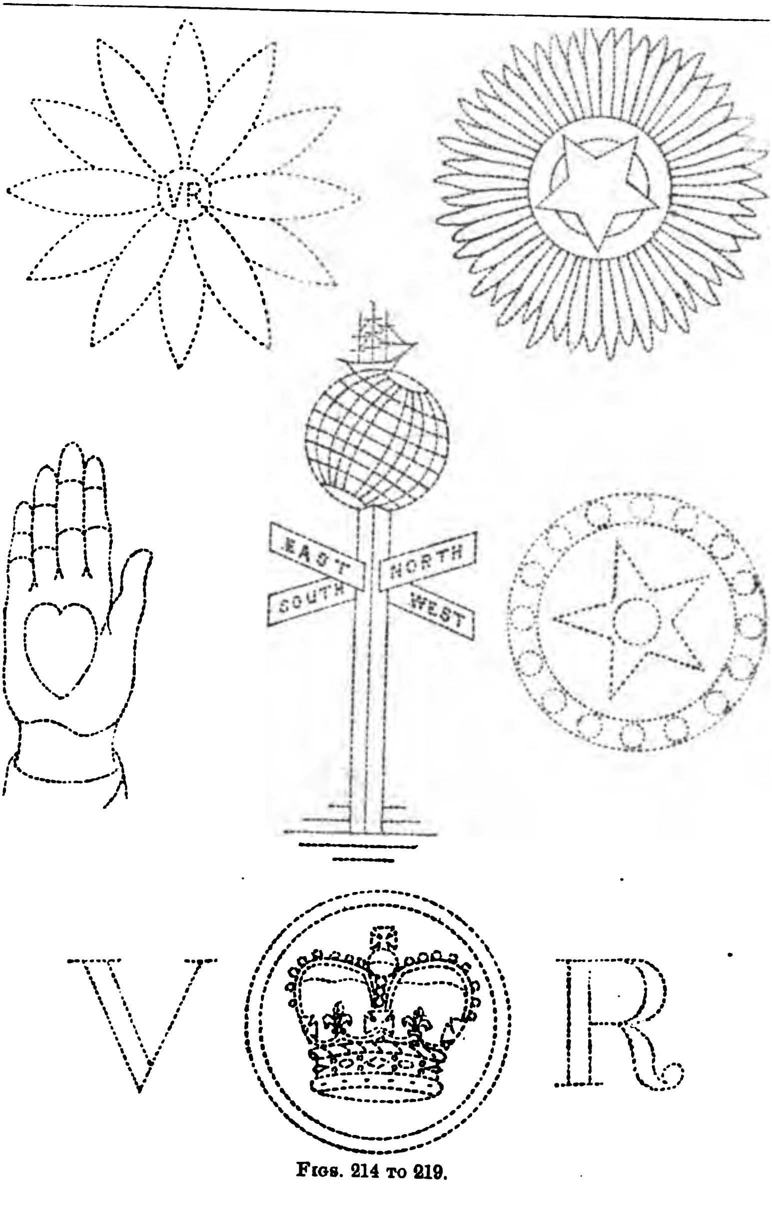
FIGS. 203 AND 204.



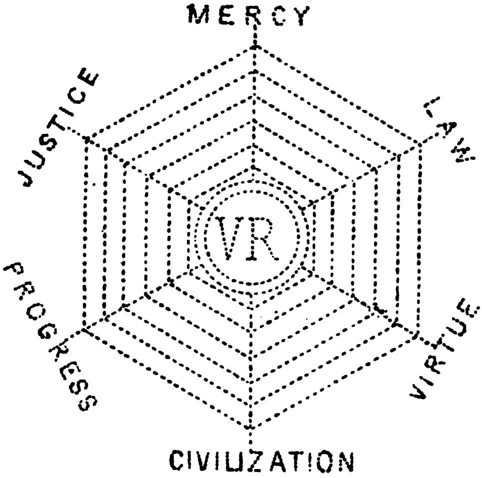
FIGS. 205 TO 211.

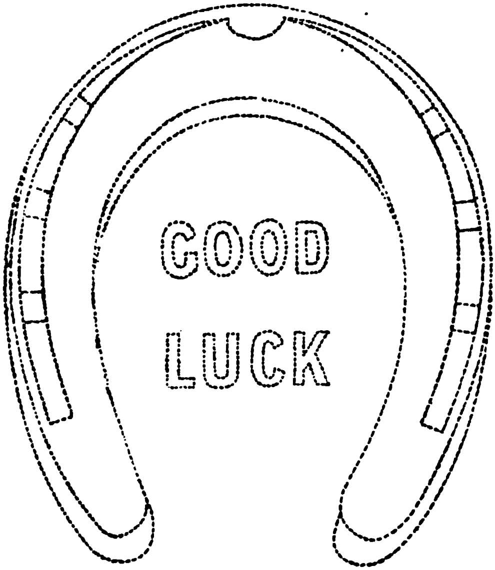


FIGS. 212 AND 213.

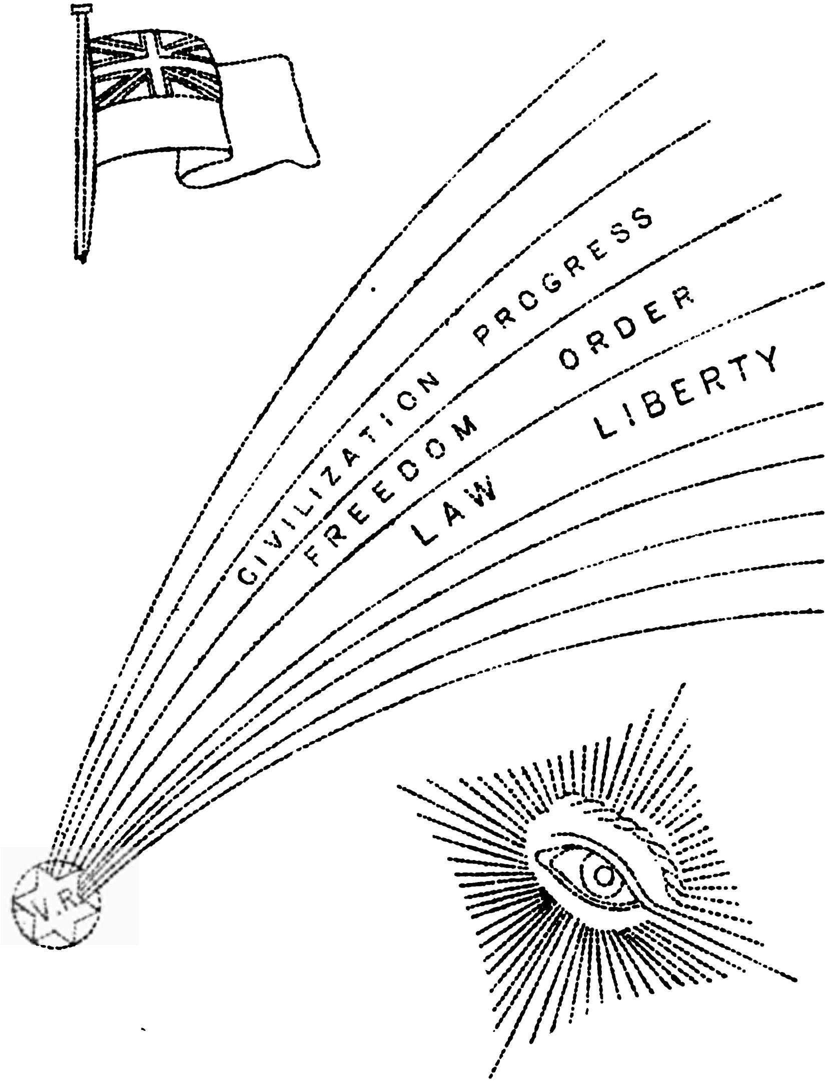


FIGS. 214 TO 219.



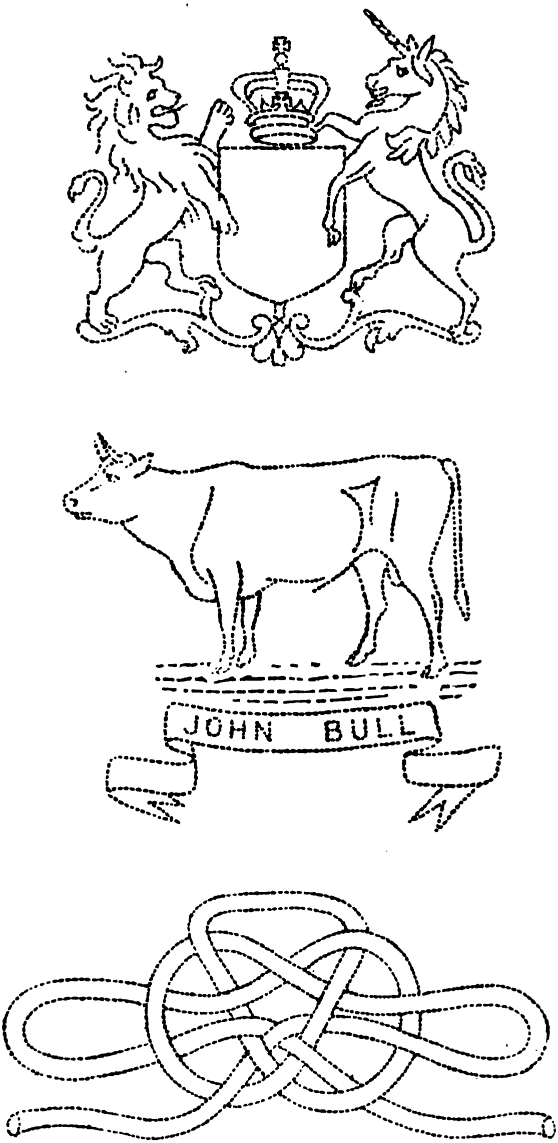


FIGS. 220 AND 221

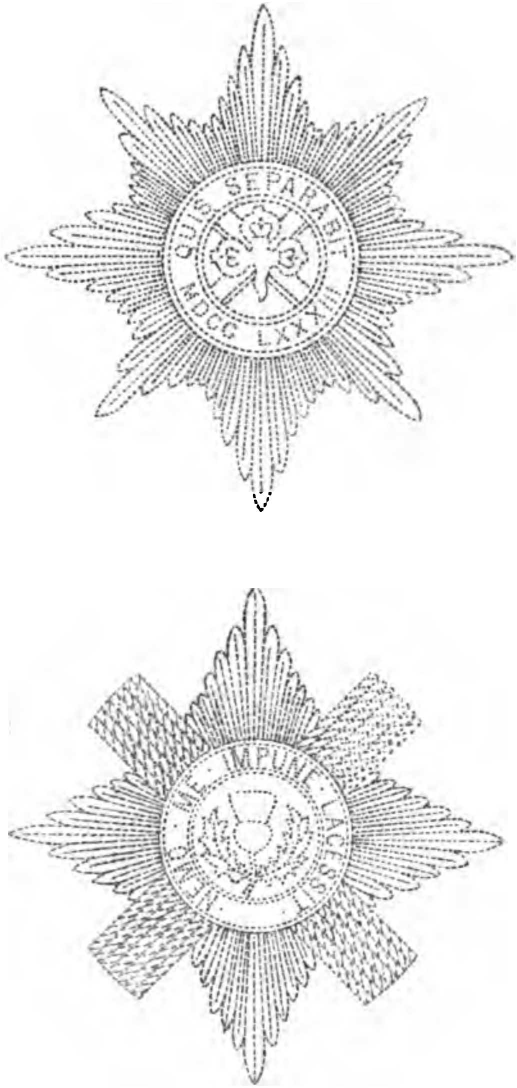


FIGS. 222 TO 224.

Figs. 225 and 226.



Figs. 227 to 229.



Figs. 230 and 231.

FIGS. 232 AND 233.

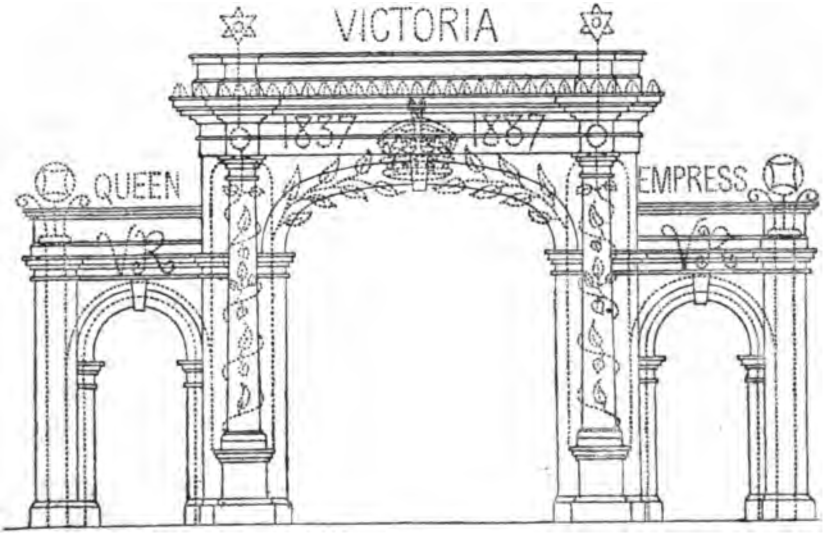


FIG. 234.

THE USE OF GAS FOR PURPOSES OTHER THAN LIGHTING.

The use of gas for cooking, heating, and motive power has made rapid strides of recent years; and the steady increase that is taking place in the consumption of gas for purposes other than illumination is a matter of interest. Twenty to twenty-five years ago this consumption was only beginning to make itself felt, yet within the brief period which has elapsed, large industries, giving employment to much capital and many workpeople, have been called into existence to produce the machinery and appliances required, to describe which would need a treatise in itself. These, which are of the most numerous and varied kind, are of great excellence, whilst improvements are constantly being effected therein.

For domestic and greenhouse use there are numberless heating stoves of superior design and workmanship, and in cooking stoves and ovens there is equal variety.

The uses to which gas may be advantageously put in every branch of trade where heat is required, are only limited by the number of such trades. For example, in coffee roasting, in the manufacture of confectionery, the baking of bread, the finishing of shoes, in dentistry, in the production of jewellery, in wire welding, tempering steel, enamelling, and many others.

The gas-engine already successfully competes with the steam motor for all purposes where the power required to be exerted is intermittent and within moderate limits.

For handiness in application, and cleanliness and safety in use, gas, as a fuel, is unsurpassed. The use of gas in these ways means a saving of time and labour, and is an important step towards the solution of the smoke difficulty in towns.

Taking its advantages in these respects into account, there is economy in its employment even when, as in scattered districts, its price per 1000 cubic feet may be considered high. In towns where the price of gas is comparatively low, there is a positive economy in its adoption, beyond the special recommendations named.

The manufacture of gas-engines was at first confined to the smaller sizes, from one man power to 10-horse power, but now larger sizes equal to as high as 100-horse power are being made.

In adopting this motor, neither boiler nor chimney are required, and hence it can be employed in buildings, and in out-of-the-way

corners in establishments where a steam engine is altogether inadmissible. It is always available for work on the opening of a tap, and it goes on working continuously day and night with the least possible attention. Moreover, the percentage efficiency of the gas-engine is greatly in excess of that evolved by the steam motor.

As a ventilating agent the gas-flame is of the greatest use, and in rooms where the means of ventilation are provided it promotes their efficiency, though it has not been employed in this direction as extensively as its merits deserve. In spacious assembly rooms in which crowded meetings are held, the gas "Sunlight," or the "Regenerative" light, with their ventilating tubes, may be recommended as superior to any other method of artificial lighting.

One of the best methods—perhaps the very best method—of reducing the proportion which capital expenditure in gas-works bears to revenue, is to cultivate a day consumption of gas, by affording facilities for and encouraging in every legitimate way the use of gas for cooking, heating, ventilating, and motive power. It is interesting to ascertain approximately, and to keep a permanent record of, the proportion of gas consumed in the daytime as compared with the night. To do this it is necessary to take the stock of gas in the holders at 8 a.m., 8 p.m., and 12 midnight.

This policy, if pursued to a successful issue, is virtually to reduce the percentage of capital in the proportion of such consumption, because the plant is brought to bear in earning profit during the daylight as well as in the lighting hours.

If local governing Authorities (or some of them) in possession of gas-works had the real, permanent good of their respective communities at heart—or were less narrow and short-sighted in their views—instead of appropriating large gas profits in aid of rates (a policy which, besides being unjust, always tends to waste and extravagance), would aim at reducing the selling price of the gas, they would, by so doing, give encouragement to the establishment and growth of what may be termed The Minor Industries, whose success, and even existence, are so largely dependent upon a cheap, cleanly, and handy fuel for heating and motive power purposes.

This wise policy of selling gas at cost price (including, of course, interest on capital) has a three-fold advantage, inasmuch as it promotes the day consumption, it goes a long way towards abolishing the smoke nuisance, and it broadens the base of the general prosperity by the encouragement it gives to the growth of a variety of trade interests.

THE RESIDUAL PRODUCTS.

One, and not the least important, of the duties of the Gas Manager is to do what in his power lies to promote the interests of the Undertaking under his charge, by utilizing the residual products of gas manufacture to the utmost extent.

It is a remarkable fact that there are no waste products in a properly conducted gas-works. The coke, breeze, tar, ammoniacal liquor, sulphur, spent lime, retort carbon, and even the clinker and ash from the furnaces are all marketable, and therefore of more or less value. The flue gases from the retort stack are even utilized for the generation of steam, and for heating the air supply to the combustion chamber where the regenerative system is applied.

Coke and Breeze.—Coke, as ordinarily produced, is not well adapted for domestic use for kitcheners, for use in greenhouses, or stoves in general; and, in consequence, its sale is often restricted. To render it suitable for these purposes, it requires to be broken into pieces of smaller and more uniform size.

Wherever means have been adopted for this purpose, the article has been found to command a ready sale; and instead of mountains of coke in every available corner of the works, the material is, as a rule, cleared out almost as quickly as it is produced.

The labour, inconvenience, and waste attendant on stacking are thus avoided, the premises can be kept in better order, and the revenue is augmented.

For breaking the coke by hand, a hammer of the form shown in Fig. 235, with a chisel edge at one end, and four prongs at the other may be recommended.

A machine for breaking coke is made by Smith, Beacock, and Tannett, of Leeds. This is used by Mr. Sellers at the York Gas-Works, who gives the cost, and describes the advantages attending its use.

" The engine (a 4-horse vertical) and breaker, and fitting up of same, cost £143; being, for the engine, £108, the breaker, £28, and fitting up, £7. By placing the engine and breaker upon one frame, so that both could be moved upon one set of wheels, the cost would be materially reduced, and the working very much improved. The machine, when at full work; will break 20 tons of coke per day. We

have one man to look after the engine, and two to feed the machine; but as the first named is not fully occupied with the engine, he assists the other two in helping carters to put the broken coke into bags, &c., the net cost of all which adds 9d. per ton to the price. Then in breaking a ton of coke, about 1 cwt. passes through the screen, and is sold as breeze at 1s. 6d. per ton, or, say, 1d. per cwt. The real result, therefore, of breaking coke stands thus: We sell our unbroken coke at 10s. per ton, and broken at 10s. 8d.; the 8d. added being 9d. per ton for labour, and coke converted into breeze by breaking, less 1d. received for breeze per ton of coke broken. The cost of maintenance of engine and breaker we consider is more than recouped by, first, the saving of labour that would have been employed in loading the coke if it had not been broken; secondly, the saving of the cost in labour and depreciation of stacking the coke if it were not sold; and, thirdly, the advantage gained in getting rid of the coke, so as to enable us to maintain our price of 10s. per ton, for upon our annual make of coke for sale a reduction of 1s. per ton would inflict a loss of £500 a year."

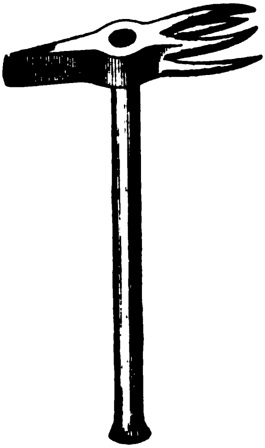


FIG. 235.

Another excellent coke breaker is that devised by Thomas and Somerville. This machine requires very little power to drive it, and the waste of coke by its use is remarkably small. At a trial of the machine at the Old Kent Road works, the following results were obtained:—

	s.	d.
500 feet of gas consumed by a 2-horse power gas-engine, at cost price of gas delivered in holder .	0	9
Oil and cotton waste	0	6
Two men supplying machine with large coke, and shovelling up broken, at 4s. 6d.	9	0
Interest and wear and tear (say)	0	3
Total per day	10	6

	s.	d.
For 80 tons of coke broken per day at the rate of .	0	1½
And for loss by dust and waste, 1 cwt. with price of coke at (say) 13s. 4d. per ton	0	8
Cost of breaking per ton .	0	9½

The coke thus manipulated finds a ready and constant market as quickly as it is produced, the result being an average net gain of 1s. 6d. per ton of coke.

Coke, immediately on being slaked with water, weighs about 15 per cent. more than when unslaked; the bulk of the moisture, however, evaporates—about 8 per cent. only being retained.

A ton of coke is about a chaldron and a half.

A chaldron of coke varies in weight from 12½ to 15 cwt.

For the quantity of coke produced by different coals, see the tables on pages 12, 13, 16, and 17.

Coal Tar.—The yield of tar from coal per ton in gas-works ranges up to 12 gallons, and from cannel up to about 17 gallons. The average production in gas-works throughout the country will not exceed 11 gallons per ton. The total production of coal tar in the United Kingdom is probably about 600,000 tons.

The utilization of the tar for its products is not pursued at many gas-works, though it is done at a few, and if well managed it is a source of profit.

Considerably more skill and care are required in the distillation of tar than in the manufacture of sulphate of ammonia; nevertheless, it is safe to predict that before many years have elapsed, this branch of practical chemistry will be widely practised on those gas-works where there is space and convenience.

The manufacture on gas-works may be wisely restricted to the distillation of the tar for the light and heavy oils, and the production of anthracene and pitch.

The principal dangers to be apprehended in the process are the leaking or boiling over of the stills and the firing of vapours, causing conflagration, and the stoppage of the pipe passages with accretions of solid matter, chiefly naphthalene, resulting in explosion; but these dangers can be minimized, or altogether averted, under proper supervision and by the use of efficient apparatus.

The specific gravity of tar produced from ordinary coal ranges from 1·120 to 1·150; that from cannel coal, from ·980 to 1·060.

TABLE

Showing about the Average Proportion of the several Products obtained from the Distillation of 10,000 *gallons of Coal Tar.* (*Dr. Letheby.*)

Ammoniacal liquor	240·0 gals.	Solvent naphtha	41·8 gals.
40 per cent. benzole	84·4 „	Last runnings	12·0 „
90 „ „	53·1 „	Dead oil	3018·7 „
Pitch	36 tons.		

TABLE

Showing the Average Percentage of the Products Obtained from 100 *Tons of Coal Tar.* (*Roscoe.*)

	1	2	
Naphtha	3·0	2·0	per cent.
Light oils and carbolic acid	1·5	0·8	„
Heavy oils, naphthalene, anthracene	35·0	25·0	„
Pitch	50·0	60·0	„
Water and loss	10·5	12·2	„
	100·0	100·0	

Mr. C. Greville Williams remarks ("King's Treatise," Vol. III., p. 281) that—"The working results to be obtained from a charge of 1200 gallons vary so greatly, according to the nature of the tar and the care with which the distillation has been made, that it is exceedingly difficult to give any average which will be satisfactory to distillers in different parts of the country. The following figures are placed side by side as extreme cases":—

		Lancashire: (Watson Smith.)	London: ("Chemistry as applied to the Arts and Manufactures.")
Ammoniacal liquor	gallons	30	50
First light oils	„	33	20
Second light oils	„	157	20
Creosote oils	„	104	250
Anthracene oils	„	229	50
Pitch	tons	3·25	4

The following yield of bye-products from each ton of tar distilled is given by Mr. Colson from his own working:—

Crude naphtha, 30 p.c., at 120° C.	6·79 gals.
Carbolic acid, crude 60° C.	3·50 „
Heavy naphtha, 20 p.c., at 160° C.	3·55 „
Creosote	58·04 „
Ammoniacal liquor, 10 oz.	5·00 „
Naphthalene	33·91 lbs.
Anthracene, 33 p.c.	13·60 „
Pitch	12·67 cwts.

The coals used were best Derbyshire, 73 per cent.; South Yorkshire, 18 per cent.; Nottinghamshire Cannel 9 per cent., and, carbonized at fairly high heats, the mixture yielded 10,436 cubic feet of 17-candle gas, 12·1 gals. tar and 32·8 gals. ammoniacal liquor of 10-oz. strength per ton. The sulphate made per ton of coal was 29·82 lbs.

Tar Pavement.—This is made of the breeze, ashes, and clinker of gas-works and mill furnaces, along with shingle or coarsely ground granite, mixed with coal tar.

A coke fire is first made on the ground, and the solid ingredients cessed in a heap round and over it; layer after layer being gradually added as the heat penetrates through the mass, until sufficient bulk of the material is ready.

If preferred, or if a large quantity of material has to be dried and heated, a raised sheet-iron floor may be made, supported on bricks, with the coke fire underneath; or a permanent fire-brick floor may be constructed, ramified with flues underneath leading to a chimney, and having a fire grate at one end.

In the meantime, whilst the solid ingredients are being dried and heated, the tar is being boiled, and, when ready, the two are taken and mixed together in small heaps (say about three ordinary barrow loads) in the proportion by measure of 1 part tar to 7 parts solid.

The whole is then turned over immediately whilst hot, and thoroughly mixed, until every particle of the solid ingredients has received a coating of tar.

The mixed material is then sorted into three separate heaps of graduated fineness, by passing it through two sieves with $\frac{3}{4}$-inch and $\frac{3}{8}$-inch meshes respectively. It is now ready for use, and may be laid down at once or kept in stock for a short time until required.

It is preferred by some to sort the solid ingredients before mixing with the tar, as the latter is liable to clog the sieves. In this case an ordinary screen, $\frac{3}{4}$ inch between the bars, and supported at an angle, is employed; and all that passes through it is afterwards riddled through a $\frac{3}{8}$-inch sieve.

The three different grades of material are then dried and made hot as described, and thoroughly mixed with hot tar in these proportions:—

1. Coarse material	1 part tar 9 parts solid	or 24 gals. tar to 1 ton solid.
2. Riddlings . .	1 part tar 7 parts solid	or 30 ,, 1 ,,
3. Fine material	1 part tar 6 parts solid	or 36 ,, 1 ,,

The footpath being properly kerbed, the upper edge of the stones standing 3 inches above the solid bottom of the path, the rough prepared material, No. 1, is put down 2 inches thick; then No. 2 about $\frac{5}{8}$ inch thick, and finally No. 3 about $\frac{3}{8}$ inch thick. Each layer as it is put down is rolled with a 10-cwt. roller until thoroughly consolidated. Corners which cannot be reached by the roller, must be consolidated by punning. Derbyshire spar or fine granite sprinkled over the surface improves the appearance of the pavement.

Three tons of the rough (No. 1) and $1\frac{1}{2}$ tons of the fine prepared material (Nos. 2 and 3) will cover 60 square yards, or a footpath 2 yards wide and 30 yards long.

Ammoniacal Liquor.—The amount of liquor obtained up to the outlet of the scrubbers per ton of coal carbonized, varies from 15 to 45 gallons of 10-oz. strength, depending on the class of coal used, and the efficiency of the apparatus for arresting the ammonia.

The product of ammoniacal water or liquor, when treated with sulphuric acid, is sulphate of ammonia; when treated with muriatic or hydrochloric acid, it is muriate of ammonia or sal ammoniac.

The manufacture of sulphate of ammonia from the ammoniacal liquor is fast becoming general in gas-works, and properly so, as the process is both simple and profitable. That it must be more profitable to use the liquor at the place of production than at a distance away, is evident, taking into account the saving of the cost of transport of a bulky material. The estimated annual make of sulphate of ammonia in the United Kingdom is 180,000 tons.

The apparatus required in its manufacture is neither complicated nor costly; the process is free from danger (though fatal accidents have occurred through carelessness, or the use of imperfect appliances), and an intelligent labourer can learn it in a week's time.

Sulphate of ammonia is manufactured either by the continuous or the intermittent system, and there is much to be said in favour of each.

In the continuous system (see Figs. 236, 237, and 238), the crude ammoniacal liquor is first pumped up into an overhead supply tank, and thence flows in a regulated stream into a tubular heater, the

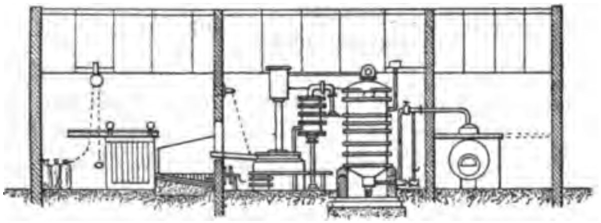


Fig. 236.

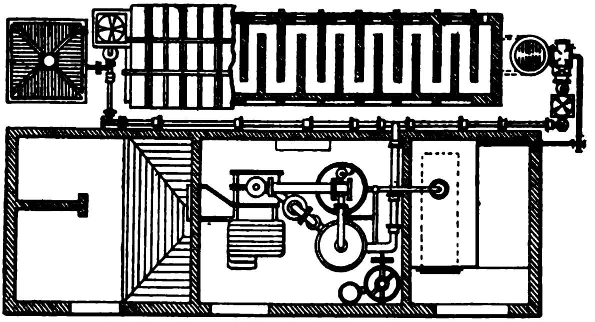


Fig. 237.

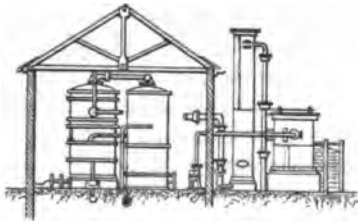


Fig. 238.

liquor traversing the tubes which are surrounded by the hot waste gases from the saturator. In this way, raised to boiling point, it goes forward into the column still, which is supplied with steam at a regulated pressure.

The upper portion of the still consists of a series of trays having each a cast-iron hood, through the serrated edges of which the heated gas travels and parts with its free ammonia. Descending into the liming chamber of the still the liquor mixes with the cream of lime supplied thereto by means of a force pump. The limed liquor then flows into the lower portion of the still, or into another smaller still adjoining, and passing over and through a second series of trays and hoods with serrated edges, the fixed ammonia is liberated.

The term "free ammonia" is not strictly accurate, but it is well understood as referring to the ammonia in combination with the feeble acids sulphuretted hydrogen and carbonic acid, as ammonia, sulphide and carbonate, and which is liberated by boiling. The "fixed ammonia," on the other hand, is that which exists in combination with hydrochloric, sulphuric, and other strong acids, as ammonia chloride, theocyanate, sulphate, theosulphate, and ferrocyanide. This is not expelled by boiling, but is liberated from these salts by decomposition in the presence of cream of lime. The proportion of free ammonia in the liquor is about 70 per cent., and of fixed ammonia about 30 per cent. of the whole.

The ammonia and other gases escape by the pipe rising from the cover of the still, and passing first through a baffle box, to have the moisture removed, they go forward into the saturator. This is made either of solid virgin lead or is a wood vessel lead-lined, and contains weak sulphuric acid, which on being sufficiently saturated with the incoming ammonia gas, precipitates sulphate of ammonia in the vessel. The sulphate is then fished out with a scoop, or is discharged by mechanical means, on to a lead draining table.

The spent liquor flowing from the still should not contain more than ·008 per cent. of ammonia. It is run into a cooling and depositing tank, and thence overflows into the drain.

The waste gases, after traversing the heater, are conveyed away by a pipe to the condenser, and forward, either through an open purifier containing oxide of iron, or through a Claus plant for the recovery of the sulphur.

In actual practice the intermittent system is a simpler process, the heat being applied directly to a boiler containing ammoniacal liquor. The firing is continued until the ammonia is driven off, when the

residuary water is run out of the boiler and the vessel re-charged with ammoniacal liquor. Steam is generated at the same time that the ammonia is driven off, and the two together conducted to the saturator, from which point the processes are similar.

1 ton of average gas coal	yields	28 lbs.	of sulphate of ammonia.
100 tons ,, ,,		$1\frac{1}{2}$ tons	,, ,,
12 tons (2622 gals.) ammoniacal liquor, 5° Twaddel, yield		1 ton	,, ,,

The strength, and consequent value of ammoniacal liquor, is commonly ascertained by Twaddel's hydrometer, and also by the quantity of sulphuric acid of the specific gravity 1845 required to neutralize the ammonia contained in one gallon.

Each degree of Twaddel is equal, as nearly as possible, to 2 oz. of acid per gallon of the liquor ; hence arises the description of its value :—

Water of	5	degrees Twaddel is called	10-oz.	liquor.
,,	6	,, ,,	12	,,
,,	7	,, ,,	14	,,

And so on, at the rate of 2 ounces for each degree, so that 10-oz., 12-oz., or 14-oz. liquor means ammoniacal liquor of such a strength that 10-oz., 12-oz., or 14-oz. of sulphuric acid, of the specific gravity of 1845, are required to neutralize the ammonia contained in a gallon of it. Each ounce strength is equal to ·847 oz. ammonia per gallon of liquor.

To convert degrees of Twaddel's hydrometer into specific gravity, multiply the number of degrees by 5, and add 1000 to the product.

EXAMPLE.—Twaddel $6 \times 5 + 1000 = 1030$ specific gravity.

To convert specific gravity into degrees of Twaddel, deduct 1000 from the specific gravity, and divide the remainder by 5.

EXAMPLE.—Specific gravity $1030 - 1000 \div 5 = 6$ degrees of Twaddel.

To determine the weight of a gallon of ammoniacal liquor of any strength find the specific gravity by the above rule. This will represent the number of ounces avoirdupois in weight per cubic foot. Divide by 16 to ascertain the number of pounds per cubic foot, and by 6·25 (gallons per cubic foot) for the weight of a gallon of the liquor.

EXAMPLE.—Required weight per gallon of 10-oz. liquor (5° Twaddel).

$(5 \times 5) + 1000 = 1025$, specific gravity and weight per cubic foot in ounces avoirdupois.

$$\frac{1025}{16} = 64 \cdot 063 \text{ lbs. per cubic foot.}$$

$$\frac{64 \cdot 063}{6 \cdot 25} = 10 \cdot 25 \text{ lbs. weight per gallon of 10-oz. liquor.}$$

Or the weight may be found more expeditiously by the rule given immediately after the next table on page 380.

It is well known that the greater the proportion of ammoniacal gas contained in a pure solution, the less the density or specific gravity of such solution. How, then, it may be asked, is the apparent contradiction to be explained, that the larger the quantity of ammonia contained in gas liquor, the greater the density?

The explanation is to be found in the circumstance that gas liquor is not a solution of ammonia pure and simple, but contains other gases in solution, and in combination with the ammonia in the form of salts, which increase its specific gravity; and the more ammonia liquor contains, the greater is its power of arresting and absorbing such other gases.

It is by reason of this latter-mentioned fact that Twaddel's hydrometer is tolerated as a gauge of the strength and value of the ammoniacal liquor of gas-works. At the best, however, its employment for this purpose is very unsatisfactory.

The method of testing by saturating the liquor with sulphuric acid is an improvement on the hydrometer; but even that is imperfect, as has been pointed out by Mr. Greville, who ascertained by experiments on nine different samples of liquor that an average of 22·5 per cent. of the ammonia present in combination was not indicated by the acid.

The mode of testing by Mr. Thomas Wills meets the difficulty. His plan is to mix with the liquor a caustic alkali for which the acids of the salts contained in the liquor have a stronger affinity than for the ammonia with which they are combined. On the mixture being strongly heated, the salts are decomposed in presence of the caustic alkali, and the ammonia being driven off in the gaseous state and conveyed into a solution of sulphuric acid is secured as sulphate of ammonia. This and the other methods of testing are fully detailed by Mr. Hartley in his *brochure* on "Ammonia Liquor Tests."

TABLE

Showing the Specific Gravity, Weight per Cubic Foot, Weight per Gallon, and Ounce Strength of Ammoniacal or Gas Liquor of different degrees Twaddel.

Degrees. Twaddel Liquor.	Specific Gravity and Weight per Cubic Foot in Ounces Avoirdupois.	Weight per Gallon. lbs.	Ounce Strength.	Degrees Twaddel Liquor.	Specific Gravity and Weight per Cubic Foot in Ounces Avoirdupois.	Weight per Gallon. lbs.	Ounce Strength.
0	1000	10·0	0	12½	1062·5	10·625	25
½	1002·5	10·025	1	13	1065	10·65	26
1	1005	10·05	2	13½	1067·5	10·675	27
1½	1007·5	10·075	3	14	1070	10·7	28
2	1010	10·1	4	14½	1072·5	10·725	29
2½	1012·5	10·125	5	15	1075	10·75	30
3	1015	10·15	6	15½	1077·5	10·775	31
3½	1017·5	10·175	7	16	1080	10·8	32
4	1020	10·2	8	16½	1082·5	10·825	33
4½	1022·5	10·225	9	17	1085	10·85	34
5	1025	10·25	10	17½	1087·5	10·875	35
5½	1027·5	10·275	11	18	1090	10·9	36
6	1030	10·3	12	18½	1092·5	10·925	37
6½	1032·5	10·325	13	19	1095	10·95	38
7	1035	10·35	14	19½	1097·5	10·975	39
7½	1037·5	10·375	15	20	1100	11·0	40
8	1040	10·4	16	20½	1102·5	11·025	41
8½	1042·5	10·425	17	21	1105	11·05	42
9	1045	10·45	18	21½	1107·5	11·075	43
9½	1047·5	10·475	19	22	1110	11·1	44
10	1050	10·5	20	22½	1112·5	11·125	45
10½	1052·5	10·525	21	23	1115	11·15	46
11	1055	10·55	22	23½	1117·5	11·175	47
11½	1057·5	10·575	23	24	1120	11·2	48
12	1060	10·6	24	25	1125	11·25	50

It will be seen by the above that the weight of the liquor in pounds avoirdupois per gallon is obtained by simply placing the decimal point after the first two figures of the number representing the specific gravity. Thus, liquor of 1025 specific gravity is 10·25 lbs.; and of 1087·5 specific gravity is 10·875 lbs. weight per gallon.

Each degree of Twaddel represents 350 grains above the weight of distilled water. Consequently, 5 degrees represent 1750 grains, or ¼ lb.; 20 degrees, 7000 grains, or 1 lb.

In Beaumé's Hydrometer, which was the first instrument of the kind, the divisions are equidistant; and it has two modes of graduation according as it is intended for liquids heavier or lighter than water. This instrument is the one principally in use on the Continent.

Beaumé's Hydrometer Compared with Specific Gravity.
For Liquids Heavier than Water.

Degrees Beaumé.	Specific Gravity.	Degrees Beaumé.	Specific Gravity.	Degrees Beaumé.	Specific Gravity.
0	1·000	26	1·206	52	1·520
1	1·007	27	1·216	53	1·535
2	1·013	28	1·225	54	1·551
3	1·020	29	1·235	55	1·567
4	1·027	30	1·245	56	1·583
5	1·034	31	1·256	57	1·600
6	1·041	32	1·267	58	1·617
7	1·048	33	1·277	59	1·634
8	1·056	34	1·288	60	1·652
9	1·063	35	1·299	61	1·670
10	1·070	36	1·310	62	1·689
11	1·078	37	1·321	63	1·708
12	1·085	38	1.333	64	1·727
13	1·094	39	1·345	65	1·747
14	1·101	40	1·357	66	1·767
15	1·109	41	1·369	67	1·788
16	1·118	42	1·381	68	1·809
17	1·126	43	1·395	69	1·831
18	1·134	44	1·407	70	1·854
19	1·143	45	1·420	71	1·877
20	1·152	46	1·434	72	1·900
21	1·160	47	1·448	73	1·944
22	1·169	48	1·462	74	1·949
23	1·178	49	1·476	75	1·974
24	1·188	50	1·490	76	2·000
25	1·197	51	1·495		

Beaumé's Hydrometer Compared with Specific Gravity.
For Liquids Lighter than Water.

Degrees Beaumé.	Specific Gravity.	Degrees Beaumé.	Specific Gravity.	Degrees Beaumé.	Specific Gravity.
10	1·000	27	0·896	44	0·811
11	0·993	28	0·890	45	0·807
12	0·986	29	0·885	46	0·802
13	0·980	30	0·880	47	0·798
14	0·973	31	0·874	48	0·794
15	0·967	32	0·869	49	0·789
16	0·960	33	0·864	50	0·785
17	0·954	34	0·859	51	0·781
18	0·948	35	0·854	52	0·777
19	0·942	36	0·849	53	0·773
20	0·936	37	0·844	54	0·768
21	0·930	38	0·839	55	0·764
22	0·924	39	0·834	56	0·760
23	0·918	40	0·830	57	0·757
24	0·913	41	0·825	58	0·753
25	0·907	42	0·820	59	0·749
26	0·901	43	0·816	60	0·745

Sulphur Recovery.—Claus's plant, made by C. and W. Walker, for the recovery of sulphur in a marketable form from the sulphuretted hydrogen passing from the saturator in the manufacture of sulphate of ammonia, is not only efficient for the purpose, but it possesses the further merit of simplicity.

The hot gases from the saturator are passed through the heater of the sulphate plant, where they are partially cooled in heating the liquor flowing towards the still, and thence through the condenser where they are cooled to the temperature of the air. They then pass into the air inlet box into which air is pumped in the proportion of $2\frac{1}{2}$ parts air to the sulphuretted hydrogen. The mixture of gas and air then enters the kiln; which is of wrought-iron lined with fire bricks, and having a fire brick grate on which rests a layer of loose broken fire bricks covered with a layer of hydrated oxide of iron about three feet deep. Passing down through the oxide of iron, the oxygen of the air combines with the hydrogen of the H_2S, forming water, leaving the sulphur to unite with the iron, forming sulphide of iron, which is immediately reoxydized by the air. The reaction takes place with such rapidity, that the mass of oxide becomes incandescent, the heat so caused volatilizing the sulphur, which goes forward with the other gases through the fire brick grating at the bottom of the kiln into the depositing chamber. This chamber is built of ordinary brickwork, excepting the portion nearest the kiln, which has a lining of fire brick. A number of transverse baffle walls in the chamber retard the flow of the gas and finely divided sulphur, cooling the latter and causing its deposition.

The chamber is covered with slate slabs, and in the side walls are doorways for clearing out the sulphur at intervals.

The waste gas remaining passes through a cast-iron scrubber filled with limestone, down which a small stream of water is constantly flowing, and in this any sulphurous acid gas which may be present is arrested. Finally, an open purifier filled with oxide of iron receives the spent gas, and arrests any H_2S that may have escaped decomposition, whilst the remaining innocuous gas escapes into the air.

Should there be an excess or insufficiency of air delivered into the kiln with the foul gases, the outlet gas of the chamber will contain traces of sulphurous acid or sulphuretted hydrogen, which are taken up respectively by the limestone scrubber and the oxide purifier.

Under proper conditions of working, the yield of marketable sulphur

reaches 90 per cent. of the sulphur passing into the kiln, and is of very pure quality.' In Figs. 286, 287, and 288, are shown C. and W. Walker's sulphate of ammonia plant, and the Claus sulphur recovery plant alongside.

Cyanogen.—Within recent years the development of the cyanide process of gold extraction has caused more attention to be paid to the recovery of the cyanogen, which has long been known to be present among the crude products of the distillation of coal in gas manufacture. There are three methods at present in use for obtaining this residual product in a marketable form. They are all based upon the conversion of the cyanogen, which exists in the raw gas chiefly as hydrocyanic acid, into a ferrocyanide of an alkali.

By the first method, the production of Prussian blue in the oxide of iron purifying material is facilitated; and after the oxide is spent, ferrocyanide of potash or soda is obtained by lixiviating the spent material with the requisite alkaline liquid. The conditions most favourable for the absorption of cyanogen by oxide of iron are, however, opposed to economical purification from sulphuretted hydrogen, so that this method of recovery is not one to be recommended.

By the second method, a salt of iron is added to the ammoniacal liquor employed in scrubbing the gas in the ordinary scrubbers or washers, whereby ferrocyanide of ammonium is formed in the liquor; whence, after the ammonia has been distilled off, it can be recovered by precipitation with copperas, or other iron salt, and subsequent conversion by an alkali, into alkaline (sodium or potassium) ferrocyanide. After separating out the ferrocyanide, any sulphocyanide contained in the ammoniacal liquor may also be recovered by precipitation with a salt of copper.

By the third method of recovery, a special scrubber is employed after the ordinary apparatus for the extraction of the ammonia and before the purifiers proper. In this vessel the gas is scrubbed with a solution of soda holding an iron salt or salts in suspension. Ferrocyanide of sodium is thereby formed directly in the scrubbing liquid, whence it can be obtained, but in a very crude and impure form, by simple evaporation.

It should be added that only in very few instances has the recovery of cyanogen been attempted on any large scale. Moreover the amount to be recovered is so very small that it is doubtful whether, except in special circumstances, its recovery would be financially

successful. The total amount available for recovery varies with different coals and conditions of carbonization. It may be taken as equivalent to from 1 lb. (or even less), to 3 or 4 lbs. of ferrocyanide (yellow prussiate) of potash per ton of coals, the higher amounts only being reached when very high heats are employed.

Applications of Sulphate of Ammonia in Agriculture.—Mr. W. Arnold gives the following general directions for the application of sulphate of ammonia in agriculture, and a list of the crops for which it is most suitable :—

Sulphate of ammonia is one of the most powerful fertilizers known to modern science. It is especially rich in nitrogen; and when used either by itself or in conjunction with farmyard manure, its good effects are written so plainly in better quality and largely increased yield of corn, that no farmer who has once used it will ever give it up, but will, on the contrary, annually increase its use upon his farm.

When bought at first hand from a gas-works, sulphate of ammonia is guaranteed to contain more than *twenty per cent. of nitrogen.* Hence its excellent effect upon all corn crops, which is chiefly expended in increasing the yield of grain, but not the straw; and there is, therefore, much less risk of "lodging" from heavy rains. This is a very important advantage. Then, manure rich in nitrogen increases the proportion of gluten in cereals; and this increase is stated by Boussingault to be as much as 10 per cent. With an increase, therefore, of 10 per cent. in quality and of 20 per cent. in yield, the use of sulphate of ammonia ought to be increased tenfold, to the great advantage of the English farmer, for both may be done.

The most suitable dressing is one of from 2 to 3 cwt. per acre, mixed with an equal weight of fine dry earth or sand, and applied early in the spring (say March or April), in moist or showery weather. It should be thoroughly mixed in a barn or dry shed; and, if at all lumpy, beaten with a shovel, and passed through a 45-mesh riddle. It should be carefully sown by hand; or, if in large quantities, with a manure drill. If wheat is to be grown entirely with sulphate of ammonia, it is better to put it on in two dressings—one half in autumn, and the other half in spring.

Upland or meadow grass, wheat, barley, oats, rye, colza, hemp, mangel-wurzel, cabbages, hops, garden produce generally, and beetroot (when grown for sugar), are the crops most largely benefited by this manure; simply because nitrogen, which is its dominant element,

enters largely into their composition. For instance, colza, hemp, and beetroot require each of them 70 lbs. per acre of nitrogen to produce a full and healthy crop; wheat, 58 lbs.; and barley, oats, and rye, 35 lbs. per acre each.

Beans, peas, sainfoin, or clover, in which potash is the dominant element, are not benefited by an application of sulphate of ammonia; but almost all other crops that can be grown will richly repay its use.

In the case of a crop thinned out by wireworm, the ravages of birds or insects, or by a severe winter, the application of 2 cwt. of sulphate of ammonia early in the spring, and lightly harrowed in, will, in many cases, cause a crop that looked only fit to plough up, to tiller freely, and grow away into a full yield of corn for the district.

Mr. Magnus Ohren states the exact quantity of sulphate of ammonia which he considers is required for different crops, as follows:—

For Grass Land.—1½ cwt. per acre; to be put on the land in the month of April, before or after a shower of rain.

For Wheat, Oats, and Barley.—1 cwt. per acre for wheat, in April; 1 cwt. per acre for oats, in April; 1½ cwt. per acre for barley in April.

For Vines.—1 bushel on the vine border, lightly forked in, in the months of March, April, May, and September. This quantity (1 bushel) to be for the nourishment of four vines.

For Onion Beds.—A good sprinkling over the beds two or three times during the growth of the onions.

For Potatoes.—1½ cwt. per acre as a top dressing, before the haulms appear above ground.

For Greenhouse Plants.—A large teacupful in a bucket of water, to water the greenhouse plants with twice a week. Not to be used, however, for heaths, rhododendrons, or orchids.

For Peach, Apricot, Plum, Currant, and Gooseberry Trees.—A similar solution to that given for greenhouse plants, in the months of March, April, and May. Rose trees and garden plants generally are benefited by the use of the solution. Celery, cabbages, and cauliflowers also grow well when watered with the solution.

For the Raising of Healthy Plants from Seeds.—Sprinkle a good quantity of the sulphate on the seed beds, and then water them a week before sowing the seeds. Melons and cucumber plants also are much benefited by the sulphate of ammonia.

Note.—All vegetation, excepting heaths, rhododendrons, and

orchids, is rendered more luxuriant, healthier, and consequently freer from the destructive attacks of insects, by the use of sulphate of ammonia. In the spring of the year vegetation requires a condensed antiseptic and nourishing food to enable it to withstand the blighting effects of the north-easterly winds, which, being the least electrical of all the winds, lower its vitality, and thus conduce to disease.

The comparative manurial value of equal weights of sulphate of ammonia and nitrate of soda, based on their nitrogen contents, is as follows:—

Sulphate. Containing 24 per cent. Ammonia.		Nitrate. 95 per cent. purity.
1·000	.. ..	0·792
1·263	.. ..	1·000

Spent Oxide of Iron.—The oxide of iron used in gas purification may be considered as "spent" when the quantity of free sulphur contained in it ranges between 45 and 55 per cent. by weight of the whole bulk of the material.

Although by continuing to use it the proportion of sulphur can be increased, it is not economical to do this beyond a certain point, as the purifiers would have to be changed more frequently, and the labour required for that purpose would be out of proportion to the benefit derived. If, however (see *ante* pp. 109 and 110), a small proportion of air or oxygen is sent through the purifiers along with the gas, revivification in *situ* is effected, and the oxide can be charged with 75 per cent. of free sulphur.

In addition to the sulphur, the spent oxide usually contains a small percentage of salts of ammonia, and some insoluble cyanides of iron, which are of value.

The spent oxide is generally sold at per unit of contained sulphur.

Mr. Andrew Stephenson has devised a handy apparatus (Fig. 239) for estimating the amount of sulphur in the oxide, and gives the following instructions for using the same:—

Weigh 100 grains of spent oxide, dry at 212° Fahr., and weigh to ascertain moisture; put the dried material in the test-tube, A, which is provided at the bottom with a filter of cotton wool.

Bisulphide of carbon is then blown from the holder, B, into the test-tube, A, on top of the spent oxide. It percolates the mass

gradually, and dissolves out the sulphur; the solution finding its way by gravitation into the flask, C, which is placed in a water-bath.

The Bunsen burner is then lighted, and the application of heat soon vaporizes the bisulphide of carbon from the flask, C. The vapour finds its way through the connecting tube into the condenser, and is recovered in the receiver, D, under water, ready for further use.

The sulphur is left in the flask (the weight of which has been previously noted); and when all the bisulphide of carbon is driven off, the quantity of sulphur may be ascertained.

Fit the filter in the test-tube with care. If too tight, it will prevent filtration; if too loose, it will permit some of the oxide to pass through.

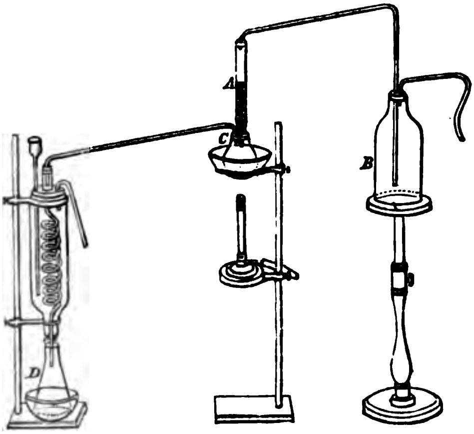


FIG. 239.

Three or four times the bulk of the oxide is about the proportion of bisulphide of carbon necessary to dissolve out all the sulphur.

It must always be borne in mind that bisulphide of carbon is very inflammable, and in the gaseous state when mixed with air in certain proportions it is explosive. The bisulphide in the holder, B, should be covered with water.

It is best to melt the sulphur in the flask before weighing, to drive off all bisulphide of carbon.

Gas Lime: Its Composition, and Use in Agriculture.—In a valuable paper on gas lime, published in the *Journal of Gas Lighting*,*

* See Vol. XIV., p. 210.

Professor Voelcker states that a copious supply of air is necessary to transform the injurious sulphur compounds contained in the material into fertilizing agents.

When exposed to the air (and the longer it is kept exposed the better), gas lime is in some respects superior to quick lime as a manure.

The oxygen of the atmosphere destroys the offensive smell, and changes the sulphuret of calcium in it—first into sulphite, and finally into sulphate of lime or gypsum, well known as a valuable fertilizing substance.

In addition to its chemical virtues, gas lime exercises a beneficial *mechanical* effect upon land, by rendering stiff, heavy, clayey land more porous and friable, and by consolidating light sandy soils.

The crops which are particularly benefited by gas lime are—clover, sainfoin, lucerne, peas, beans, vetches, and turnips. It is a useful fertilizer for permanent pasture, destroying the coarser grasses, and favouring the growth of a sweeter and more nutritious herbage.

It kills moss, heath, feather grass, and other plants characteristic of peaty land, its application to which cannot be too strongly recommended.

As a general rule, two tons per acre is the quantity of gas lime which ought to be put on land.

The proper time for its application is in the autumn or winter.

During the period of storage, the heap should be turned over once or twice to ensure its complete exposure to the air.

The following is an analysis by Professor Voelcker of a sample of gas lime, *kept long enough to be used with safety as a manure.*

Composition of Gas Lime (Dried at 212° Fahr.).

	Per Cent.
Water of combination and a little organic matter	7·24
Oxides of iron and alumina, with traces of phosphoric acid	2·49
Sulphate of lime (gypsum)	4·64
Sulphite of lime	15·19
Carbonate of lime	49·40
Caustic lime	18·23
Magnesia and alkalies	2·53
Insoluble siliceous matter	0·28
	100·00

In fresh gas lime the proportion of water varies usually from 30 to 40 per cent.

TABLE

Showing the results Obtained by the application of certain Manures to Land. (Mr. Wilson, of Largs.)

Manure.	Produce of the Lot in lbs.	Pounds of Hay per Acre.	Increase per Acre over that Untouched.
Left untouched	420	3360	—
2½ barrels of quicklime	602	4816	1456
1 ton of lime from gas-works . . .	651	5208	1848
4½ cwt. of wood charcoal powder . .	665	5320	1960
2 bushels of bone dust	693	5544	2184
18 lbs. of nitrate of potash	742	5936	2576
20 lbs. of nitrate of soda	784	6272	2912
10 bushels of soot	819	6552	3192
28 lbs. of sulphate of ammonia . . .	874	6776	3416
100 gals. of ammoniacal liquor from gas-works	945	7562	4202

The land was a piece of three years' old pasture, of uniform quality, divided into 10 lots of 20 perches each. All the lots were manured at the same time with the articles given in the table, and the grass cut and made into hay in July. Each application cost the same.

Ammoniacal liquor is best applied at the following strength :—

Ammoniacal liquor (5° Twaddel)	1 part.
Water	7 parts.

The proper time for its application is in the spring, after the grass has commenced growing, and during cloudy weather. It may be sprinkled on the land as water is applied to the streets of towns to lay the dust.

COAL PRODUCTS.

Table of the Principal Substances Obtained in the Manufacture of Coal Gas, and in the Utilization of the Residual Products arising therefrom.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Acetic Acid	$C_2H_4O_2$	Acid	1·062	248°	Contained in coal tar.
Acetylene, or Klumine	C_2H_2	Neutral	·898 (air = 1)	..	1 vol. C vapour, 1 H. One of the hydrocarbons in coal gas, but in very small proportion. Its own bulk absorbed by water. This hydrocarbon in combination with copper produces a compound of a highly explosive nature, giving rise to obstructions in copper pipes, and in the attempt to remove which, dangerous accidents have occurred.
Acridene	..	Alkaline	..	..	One of the coal tar alkaloids.
Alizarene (Lazaric Acid)	$C_{14}H_8O_4$	Acid	..	..	The colouring principle of the madder root. Derived from anthracene by the addition of 4 atoms of O, and the abstraction of 2 atoms of H.
Alliaceous Oils	..	Neutral	..	..	Contained in coal tar.
Alum (Ammonia-Alum)	$Al_2(NH_4)_2 4SO_4 + 24H_2O$		..	..	Obtained by adding a solution of sulphate of ammonia to one of sulphate of alumina.
Ammonia	NH_3	Alkaline	·59 (air = 1)	27°	1½ Vol. H, 1 vol. N. Exists in coal gas both in a free state and in combination. Attacks copper and brass fittings and in burning with the gas forms nitric acid. Water at common temperature absorbs 783 times its volume of the gas, its removal is therefore easily effected. Test, moistened tumeric paper.
Ammoniacal Liquor	..	Alkaline	..	..	The aqueous portion of the condensed coal products, being a solution, chiefly of carbonate, sulphide, and sulphocyanide of ammonium. Average yield of coal, 25 gals. per ton of 8-oz. liquor, equal to 4° Twaddel.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Amyl	$C_{10}H_{22}$	Neutral	4·9 (air = 1)	..	5 vols. C, 11 vols. H. A constituent (hydrocarbon) of coal gas. Belongs to the alcohol radical series of hydrocarbons.
Amylene	C_5H_{10}	Neutral	2·4 (air = 1)	As a liquid 102°	2½ vols. C, 5 vols. H. One of the hydrocarbons in coal gas, of the olefiant gas series. It is also a constituent of coal tar.
Amylhydride	C_5H_{12}	Neutral	2·49 (air = 1)	..	2½ vols. C, 6 vols. H. Of the marsh gas series of hydrocarbons.
Anilene	C_6H_7N	Alkaline	1·080	360°	The base of all the dyes bearing this name, and is obtained by the action of nascent hydrogen on nitro-benzole.
Anthracene	$C_{14}H_{10}$	Neutral	1·147	680°	Contained in the least volatile portion of the coal oils. The colouring principal of madder, alizarene, is derived from this substance.
Anthraquinone	$C_{14}H_8O_2$	Acid	..	..	Derived from anthracene.
Antipyrene	..	..	..	..	A coal tar product. Said to be the most powerful agent known for reducing temperatures in fevers.
Aqueous Vapour . . .	H_2O	Neutral	·622 (air = 1)	..	A constituent of raw gas, and removed, though not entirely, by condensation.
Benzylic Hydride, see Toluole. . .					
Benzol, Benzene, or Phene	C_6H_6	Neutral	·850	176°	Remarkable for its solvent power for caoutchouc, gutta-percha, resins, and fats. Used also for preparing varnishes, for removing grease spots, and cleansing soiled white kid gloves. It is the chief constituent of naphtha, and, treated with nitric acid, yields nitro-benzole, from which anilene is derived.
Benzol Vapour, or Bicarburetted Hydrogen.	C_6H_6	Neutral	2·7 (air = 1)	..	3 vols. C, 3 vols. H. One of the hydrocarbons existing in coal gas. Slightly absorbed by water; easily condensed by cold. Like the other richer hydrocarbons, it is absorbed by vulcanized india-rubber tubing.
Bicarburetted Hydrogen, see Benzole Vapour.					

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Bisulphide of Carbon . .	CS_2	Acid	2·64 (air = 1)	The liquid 117°	One of the impurities in coal gas; and one of the most difficult to eliminate. Not condensed by cold; not soluble in water. Removable by sulphide of calcium (foul lime) in the purifiers.
Bisulphuret of Carbon, see Bisulphide of Carbon.					
Brunolic Acid	..	Acid	..	..	Contained in coal tar.
Butyl	C_4H_9	Neutral	3·94 (air = 1)	..	4 vols. C, 9 vols. H. A hydrocarbon existing in coal gas, and belonging to the alcohol radical series.
Butylene, Tetrylene, Ditetryl, or Oil Gas.	C_4H_8	Neutral	1·94 (air = 1)	..	2 vols. C, 4 vols. H. A hydrocarbon found in coal gas, and of the olefiant gas series. It is also a constituent of coal tar.
Butyl-hydride	C_4H_{10}	Neutral	Gas 2· (air = 1) Liquid ·600	..	2 vols. C, 5 vols. H. A hydrocarbon existing in coal gas, and belonging to the marsh gas series. It exist also as a colourless liquid, and is the lightest of all known liquids; its specific gravity being only ·600.
Butyric Acid	$C_4H_8O_2$	Acid	·973	314°	One of the acids of coal tar.
Caproylene, see Hexylene.					
Carbolic Acid, Phenic Acid or Phenol.	C_6H_6O	Acid	1·065	370°	Contains valuable antiseptic and disinfecting properties, and is used for making dyes. It is obtained from coal tar.
Carbon	C	..	..	..	This element is the basis of the illuminating qualities of coal gas. In the flame of hydrogen its particles are heated to incandescence, and emit intense light. Afterwards uniting with the oxygen of the atmosphere to form carbonic acid, one of the products of the combustion of coal gas. The solid deposit upon the interior surface of gas-retorts is almost pure carbon, and is used in the construction of the Bunsen galvanic battery, and for the carbon points of candles producing the arc electric light.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Carbonate of Ammonia	$(NH_4)_2CO_3$	..	..	..	A salt produced by the chemical combination of ammonia with carbonic acid gas. When exposed to the atmosphere, it gradually attracts more carbonic acid from the air, and becomes bicarbonate of ammonia, which is used by bakers, instead of yeast, in preparing light and spongy cakes.
Carbonic Acid, called also Black Damp.	CO_2	Acid	1·52 (air = 1)	..	½ vol. C vapour, 1 vol. O. The presence of this impurity in common coal gas to the extent of only 1 per cent. will diminish the light about 5 per cent. Soluble in its own volume of water. Is entirely removed from gas by the use of lime. Test, lime water.
Carbonic Oxide.	CO	..	·967 (air = 1)	..	½ vol. C vapour, ½ vol. O. Exists in coal gas in small proportion. 100 vols. water absorb about 2·43. Test, an ammoniacal solution of subchloride of copper.
Cespitene	$C_5H_{13}N$	Alkaline	..	205°	A constituent of coal tar.
Chinolene	C_9H_7N	Alkaline	1·081	462°	Do. Do.
Chrysene.	$C_{18}H_{12}$	Neutral	..	..	Do. Do.
Coke	..	..	..	..	The valuable product obtained in the manufacture of coal gas. Consists mainly of carbon.
Collidene.	$C_8H_{11}N$	Alkaline	·937	354°	A constituent of coal tar, contained in the light oil.
Condensable Hydrocarbons.	..	..	..	..	Includes all the hydrocarbons existing in coal tar. But indeed the whole of the more volatile hydrocarbons existing in coal gas are liable to be condensed by extreme cold, hence the importance of preventing the gas from being subjected to a temperature below 50° Fahr.
Coridene.	$C_{10}H_{15}N$	Alkaline	..	412°	A constituent of coal tar.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Creosote, or Dead Oil . .	..	..	..	..	Obtained in large quantities in the distillation of coal tar. Used in the preservation of timber, such as railway sleepers, &c. It is also useful as a fuel, and in combination with caustic soda and tallow, as a dip for washing sheep.
Cresylic Acid, or Cresol .	$C_7 H_8 O_2$	Acid	..	397°	One of the coal tar acids.
Crude Naphtha. . . .	..	Neutral	..	..	The first naphtha obtained in the distillation of coal tar, and which comes over at a temperature from 180° to 310° Fahr.
Cryptidene	$C_{11} H_{11} N$	Alkaline	..	525°	One of the coal tar alkaloids.
Cumene	$C_9 H_{12}$	..	..	331°	A constituent of coal tar, obtained from the light oil.
Cumidene	$C_9 H_{13} N$	Alkaline	·952	437°	One of the coal tar alkaloids.
Cumole	$C_9 H_{12}$	Neutral	Liquid ·870 Gas 4·15 (air = 1)	302°	A constituent both of coal gas and tar of the benzole series of hydrocarbons, 4½ vols. C, 6 vols. H.
Cyanogen	$C_2 N_2$	..	1·8 (air = 1)	..	1 vol. N, 1 vol. C. Produced during the destructive distillation of coal, but, with the exception of a very small proportion, which passes into the gas, is condensed and carried into the tar well along with the ammoniacal liquor. Not readily absorbed by water; but by alkalies and alkaline sulphides. Combined with iron it forms Prussian blue, and is the cause of the bluish-green colour in spent lime. It is used in the cyanide process of gold extraction. In union with ammonium sulphide, it forms sulpho-cyanide of ammonium, a substance used by photographers, and in the preparation of the constituent of the toys known as "Pharaoh's Serpents." It is a highly poisonous gas.
Cymidene	$C_{10} H_{15} N$	Alkaline	..	482°	An alkaline body contained in coal tar.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Cymole or Cymene . .	$C_{10} H_{14}$	Neutral	Liquid ·861 Gas 4·63 (air = 1)	349°	A constituent both of coal gas and tar; of the benzole series of hydrocarbons. 5 vols. C, 7 vols. H.
Dead Oil, see Creosote.					
Decyl	$C_{10} H_{21}$	Neutral	..	..	Constituent of coal tar.
Decylene.	$C_{10} H_{20}$	Neutral	..	..	Do. do.
Decyl-hydride	$C_{10} H_{22}$	Neutral	..	..	Do. do.
Disulphide of Carbon, see Bisulphide of Carbon.					
Ditetryl, see Butylene.					
Elayl, see Olefiant Gas.					
Ethyl	$C_2 H_5$	Neutral	2· (air = 1)	..	A constituent of coal gas. 2 vols. C, 5 vols. H.; 2·15 vols. soluble in 100 vols. water.
Ethylamene	$C_2 H_7 N$	Alkaline	..	60°	A constituent of coal tar.
Ethylene, see Olefiant Gas.					
Ethyl-hydride	$C_2 H_6$	Neutral	1·04 (air = 1)	..	A constituent of coal gas. 1 vol. C, 3 vols. H; of the marsh gas series of hydrocarbons.
Eupion	..	..	..	..	Obtained from coal tar, and proposed to be used as a substitute for chloroform.
Fire-damp, see Light Carburetted Hydrogen.					
Green Oil	..	..	..	..	This follows the dead oil in the distillation of coal tar, and mixed with resin and oil, is used for making railway grease. Lamp black, from which printers' ink is prepared, is also made from it.
Heptylene, see Œnanthylene.					

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Hexyl	$C_6 H_{12}$	Neutral	..	..	A constituent of coal gas.
Hexylene, or Caproylene.	$C_6 H_{14}$	Neutral	..	160°	A constituent of coal tar, contained in the light oil.
Hexyl-hydride	$C_6 H_{14}$	Neutral	..	154°	A constituent of coal gas.
Hydric Sulphide, see Sulphuretted Hydrogen.					
Hydride of Amyl, see Amyl-hydride.					
Hydride of Butyl, see Butyl-hydride.					
Hydride of Decyl, see Decyl-hydride.					
Hydride of Ethyl, see Ethyl-hydride.					
Hydride of Hexyl, see Hexyl-hydride.					
Hydride of Methyl, see Methyl-hydride, or Light Carburetted Hydrogen.					
Hydride of Octyl, see Octyl-hydride.					
Hydride of Phenyl, see Benzole.					
Hydride of Propyl, see Propyl-hydride.					
Hydrocarbons	..	..	..	..	The different compounds of carbon and hydrogen, gaseous or volatile and condensable, contained in illuminating gas and in coal tar, constituting the light-giving material of the former and the rich and valuable products of the latter.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Hydrocyanic Acid	HCN	Acid	..	..	Obtained from coal tar.
Hydrogen	H	..	·0691 (air = 1)	..	The lightest known substance in nature. 100 vols. water absorb 1·93. One of the chief constituents of coal gas, in which it exists to the extent of 12 to 50 per cent. Pure hydrogen gives scarcely any light during combustion, but when solid substances are suspended in the flame, which has the high temperature of 5898° Fahr., considerable light is emitted.
Hydrosulphocyanic Acid.	S (CN) H	Acid	..	..	Obtained from coal tar.
Hydrosulphuric Acid, see Sulphuretted Hydrogen.					
Klumine, see Acetylene					
Leucolene, or Quinolene	$C_9 H_7 N$	Alkaline	..	455°	Obtained from coal tar.
Lepidene	$C_{10} H_9 N$	Alkaline	1·072	510°	Do. do. obtained from the heavy oil.
Light Carburetted Hydrogen, also named Marsh Gas, Pit Gas, Fire Damp, and Hydride of Methyl	$C H_4$	Neutral	·56 (air = 1)	..	A constituent of coal gas to the extent of 30 to 60 per cent. ½ vol. C vapour, 2 vols. H. Not condensed by cold, and not easily decomposed by heat. 100 vols. water absorb 3·91 vols.
Light Oil	..	..	..	..	The oil that follows the crude naphtha, and precedes the creosote or dead oil in the destructive distillation of coal tar. It is usually redistilled along with the crude naphtha for obtaining benzole. The two are also used for making black varnish, or for burning in the common naphtha lamp.
Liquid Ammonia	..	Alkaline	·880	..	A solution of ammonia gas in water.
Lutidene	$C_7 H_9 N$	Alkaline	·946	309°	A constituent of coal tar, contained in the light oil.
Marsh Gas, see Light Carburetted Hydrogen.					

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Mesitylene	$C_9 H_{12}$	..	..	325°	A constituent of coal tar, obtained from the light oil.
Methyl	$C_2 H_6$	Neutral	1·04 (air = 1)	..	1 vol. C, 3 vols. H. 100 vols. water absorb 5·08 vols. A constituent of coal gas of the alcohol radical series of hydrocarbons.
Methylamene	$C H_5 N$	Alkaline	..	..	Obtained from coal tar.
Methylene	$C H_2$	Neutral	·484 (air = 1)	..	A constituent of coal gas of the olefiant gas series of hydrocarbons. ½ vol. C, 1 vol. H. Not soluble in water.
Methyl-hydride, see Light Carburetted Hydrogen.					
Mirbane, Essence of, see Nitro-benzole.					
Muriate of Ammonia, or (when sublimated) Sal Ammoniac.	$NH_3 HCL$ or $NH_4 CL$	Alkaline	..	..	The important salt which is produced from ammoniacal liquor when the latter is saturated with muriatic or hydrocholoric acid. Nearly all the medicinal preparations of ammonia are obtained from this salt. Used also in fixing the colours in woollen.
Naphtha, see Crude Naphtha.					
Naphthalene	$C_{10} H_8$	Neutral	1·153	414°	5 vols. C, 4 vols. H. A constituent of coal tar.
Naphthalene Vapour	$C_{10} H_8$	Neutral	4·42 (air = 1)	..	5 vols. C, 4 vols. H. Not soluble in water, but by naphtha and coal tar. Quickly deposited by cold.
Naphthylamene	$C_{10} H_9 N$	Neutral	..	..	A compound produced from naphthalene.
Nitric Acid	HNO_3	Acid	1·51	Not constant.	A small proportion of this acid is formed when nitrogen is burnt with coal gas.
Nitro-benzol, Nitrobenzene, or Essence of Mirbane.	$C_6 H_5 NO_2$	Neutral	..	..	The substance produced by the action of fuming nitric acid on benzole naphtha, and which is used for the manufacture of aniline colours. It is also used as an odour resembling oil of bitter almonds, to perfume soaps and flavour confectionery.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Nitrogen	N	..	·9713 (air = 1)	..	100 vols. water absorb 1·48 vol. The presence of nitrogen in coal gas is sometimes due to irregularity in the working of the exhauster, by which a vacuum is created, and air drawn in through the fissures of the retorts. The nitrogen contained in the coal, and which is eliminated by distillation, is evolved in combination with hydrogen as ammonia. Its effect is to injure the illuminating power.
Octyl	$C_8 H_{17}$	Neutral	..	..	A constituent of coal gas.
Octylene	$C_8 H_{16}$	Neutral	..	..	Do. do.
Octyl-hydride	$C_8 H_{18}$	Neutral	..	246°	Do. do. contained in the light oil.
Œnanthylene	$C_7 H_{14}$	Neutral	..	210°	Obtained from coal tar, from the light oil.
Olefiant Gas, Ethylene, or Elayl.	$C_2 H_4$	Neutral	·968 (air = 1)	..	1 vol. C, 2 vols. H; 100 vols. water absorb 16. Condensable by cold and great pressu re. Exists in coal gas in proportions varying from 3 to 27 per cent., and contributes greatly to its illuminating power. It contains twice as much carbon as light carburetted hydrogen. Test, brown or fuming sulphuric acid.
Oxygen	O	..	1·105 (air = 1)	..	2·99 vols. absorbed by 100 vols. water. The presence of oxygen in coal gas is due (like nitrogen) to the drawing in of air through the retorts and apparatus by too rapid working of the exhauster, and also to the opening of the retorts and purifiers for charging and discharging. 2 per cent. of air injures the illuminating power of the gas to the extent of 10 per cent.; 7 per cent. of air diminishes the light one-half, whilst about 25 per cent. of air practically destroys it.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Paraffin	$C_{17}H_{36}$ to $C_{27}H_{56}$	Neutral	·870	..	A colourless, solid, crystalline, fatty substance, chiefly obtained from the tar from Boghead cannel. It is manufactured into candles, giving a brilliant white light; and oil of high lubricating properties is made from it. Paraffin oil will only burn in the presence of a wick, and is therefore perfectly safe.
Paranaphthalene, see Anthracene.					
Parvolene, see Cumidene.					
Pentahirolene	$C_{13}H_{15}N$	..	..	..	A constituent of coal tar, obtained from the heavy oil.
Pentylene	C_5H_{10}	..	..	88°	A constituent of coal tar, contained in the light oil.
Phenic Acid, see Carbolic Acid.					
Phlorylic Acid, or Phlorol	$C_8H_{10}O$	Acid	..	424°	Do. do.
Picolene	C_6H_7N	Alkaline	·961	273°	Do. do. contained in the light oil.
Pit Gas, see Light Carburetted Hydrogen.					
Pittacal	..	..	..	..	Found in the heaviest portions of the coal tar oil.
Pitch	..	..	.	..	The residue remaining of the distillation of coal tar, of which it constitutes about 66 per cent. by weight. It is extensively used for asphalting.
Propyl	C_3H_7	Neutral	2·97 (air = 1)	..	A constituent of coal gas, of the alcohol radical series of hydrocarbons. 3 vols. C, 7 vols. H. Not soluble in water.
Propylene, or Tritylene .	C_3H_6	Neutral	1·455 (air = 1)	..	A constituent both of coal gas and coal tar. Condensed by cold and pressure. Of the olefiant gas series of hydrocarbons. 1½ vol. C, 3 vols. H.
Propy-hydride	C_3H_8	Neutral	1·522 (air = 1)	..	A constituent of coal gas, of the marsh gas series of hydrocarbons. 1½ vols. C, 4 vols. H.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Pyrene	$C_{16} H_{10}$	Neutral	..	..	A constituent of coal tar. White crystalline body.
Pyridene, see Pyrrhidene.					
Pyrrhidene	$C_5 H_5 N$	Alkaline	·986	243°	A constituent of coal tar, contained in the light oil.
Pyrrol	$C_4 H_5 N$	Alkaline	1·077	271°	A constituent of coal tar, contained in the light oil.
Quinolene, see Leucolene.					
Rosolic Acid.	$C_{19} H_{14} O_3$	Acid	..	..	Do. do.
Rubidene.	$C_{11} H_{17} N$	Alkaline	..	446°	Do. do.
Sal Ammoniac, see Muriate of Ammonia.					
Spent Lime, see also Sulphide of Calcium.	..	..	..	..	The foul lime of the purifiers. Used as a manure or top dressing for land.
Spent Oxide of Iron	..	..	..	..	The hydrated peroxide of iron, employed in abstracting the sulphuretted hydrogen from the gas, having become charged with free sulphur to the extent of 40 to 75 per cent. by a succession of foulings and revivifications, is used by the manufacturing chemists for making sulphuric acid.
Sulphate of Ammonia.	$(NH_4)_2SO_4$	..	..	..	The valuable salt produced by the neutralization of the ammonia from ammoniacal liquor with sulphuric acid. Largely used as a manure, and, by the addition of a solution of sulphate of alumina, in the manufacture of ammonia alum.
Sulphide of Calcium, or Spent Lime.	..	..	..	..	The "fouled" lime of the purifiers, and which is efficacious in absorbing from the gas the bisulphide of carbon impurity, and the sulphur compounds other than sulphuretted hydrogen.
Sulphide of Carbon, see Bisulphide of Carbon					

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Sulphocyanogen . . .	SCN	..	..	..	A constituent of raw gas.
Sulpho-hydrocarbons . .	..	..	..	..	Sulphur impurities existing in coal gas.
Sulphur	S	..	..	570°	In the best gas-producing coals the amount of sulphur present rarely exceeds $1\frac{1}{2}$ per cent., generally it is much less. In the process of distillation about one-half the contained sulphur remains in the residual coke, whilst the other half is volatilized, and, combining with H and C, constitutes impurities requiring removal.
Sulphuret of Carbon, see Bisulphide of Carbon.					
Sulphuretted Hydrogen .	H_2S	Acid	1·1747 (air = 1)	..	The chief impurity in raw or crude coal gas. It is entirely removed by the use of lime or oxide of iron. It is an inflammable gas, and generates sulphurous acid in burning. 1 vol. of water at 60° absorbs 3·23 vols. of the gas. Test, acetate of lead or nitrate of silver in solution.
Sulphuric Acid	H_2SO_4	Acid	1·845	338°	This, which is the most important and useful of all the acids, is largely manufactured from the sulphur contained in the spent oxide of iron, after having been used in the purification of coal gas from sulphuretted hydrogen.
Sulphurous Acid (or Sulphur Dioxide).	SO_2	Acid	2·247 (air = 1)	..	This gas is produced when sulphur and its compounds are burnt. Hence, illuminating gas containing sulphur yields it during combustion. The quantity given out, however, even with the most impure gas (say, with 40 grains sulphur in the 100 feet), is so inappreciable as to be perfectly innocuous in its effects, especially where the smallest attention is paid to ventilation.

Name of Product.	Formula or Symbol.	Reaction.	Specific Gravity Water = 1.	Boiling Point. Degrees Fahrenheit.	Remarks.
Tar	..	..	Ordinary Coal Tar. 1·120 to 1·150 Cannel Coal Tar ·980 to 1·060	..	The well-known complex, viscid liquid, produced in the destructive distillation of coal, and from which a great variety of valuable products is obtained. It consists almost entirely of hydrocarbon compounds, with a varying proportion of solid carbon. Tar, on distillation, yields on an average— 2·4 per cent. ammoniacal liquor 1·6 " crude naphtha 1·2 " light oil 28·8 " creosote or dead oil 66·0 " pitch 100·0
Tetrylene, see Butylene.					
Thiocyanogen, see Sulphocyanogen.					
Toluidene	$C_7 H_9 N$	Alkaline	..	388°	A constituent of coal tar.
Toluole	$C_7 H_8$	Neutral	Liquid ·870 Gas 3·179 (air = 1)	232°	A constituent both of coal gas and tar. Of the benzole series of hydrocarbons. 3½ vols. C, 4 vols. H. Not soluble in water.
Tritylene, see Propylene.					
Validene	$C_{16} H_{21} N$	..	..	..	A constituent of coal tar, obtained from the heavy oil.
Viridene	$C_{12} H_{19} N$	Alkaline	..	484°	A constituent of coal tar.
Water.	$H_2 O$	Neutral	1·000	212°	Produced as aqueous vapour, in more or less proportion, during the distillation of coal. It is also one of the products of the combustion of coal gas, from the union of the hydrogen of the gas with the oxygen of the air.
Xylene	$C_8 H_{10}$	..	..	282°	The base of xylidene, obtained from the light oil. Used in the preparation of scarlet dyes.
Xylidene, see Collidene.					
Xylole	$C_8 H_{10}$	Neutral	Liquid ·867 Gas 3·662 (air = 1)	259°	A constituent both of coal gas and tar. Of the benzole series of hydrocarbons. 4 vols. C, 5 vols. H. Not soluble in water.

TABLE OF ELEMENTARY SUBSTANCES.

Names of Elements.	Symbols.	Atomic Weights.	Names of Elements.	Symbols.	Atomic Weights.
Aluminium . . .	Al	27·04	Mercury (Hydrarg.).	Hg	199·8
Argon	A	20	Molybdenum . . .	Mo	95·9
Antimony (Stibium) .	Sb	119·6	Nickel	Ni	58·6
Arsenic	As	74·9	Niobium	Nb	93·7
Barium	Ba	136·86	Nitrogen	N	14·01
Beryllium	Be	9·08	Osmium	Os	195
Bismuth	Bi	207·5	Oxygen	O	15·96
Boron	B	10·9	Palladium . . .	Pd	106·2
Bromine	Br	79·76	Phosphorus . . .	P	30·96
Cadmium	Cd	111·7	Platinum	Pt	194·3
Cæsium	Cs	132·7	Potassium (Kalium).	K	39·03
Calcium.	Ca	39·91	Rhodium	Rh	104·1
Carbon	C	11·97	Rubidium	Rb	85·2
Cerium	Ce	141·2	Ruthenium . . .	Ru	103·5
Chlorine.	Cl	35·37	Samarium. . . .	Sm	148·9
Chromium	Cr	52·45	Selenium	Se	78·87
Cobalt	Co	58·6	Scandium	Sc	43·97
Copper (Cuprum) . .	Cu	63·18	Silicon	Si	28·3
Didymium	D	145	Silver (Argentum) .	Ag	107·66
Erbium	E	166	Sodium (Natrium) .	Na	23
Fluorine.	F	19·06	Strontium . . .	Sr	87·3
Gallium	Gu	69·6	Sulphur	S	31·98
Germanium . . .	Ge	71·9	Tantalum	Ta	182
Gold (Aurum) . . .	Au	196·8	Tellurium	Te	126·3
Helium	He	2	Thallium	Tl	203·7
Hydrogen	H	1	Thorium	Th	231·96
Indium	In	113·4	Tin (Stannum) . .	Sn	117·35
Iodine	I	126·54	Titanium	Ti	48
Iridium	Ir	192·5	Tungsten (Wolfram)	W	183·6
Iron (Ferrum) . . .	Fe	55·88	Uranium	U	239·8
Lanthanum . . .	La	138·5	Vanadium. . . .	V	51·1
Lead (Plumbum) . .	Pb	206·39	Ytterbium. . . .	Yb	171·7
Lithium	Li	7·01	Yttrium	Y	89·6
Magnesium . . .	Mg	23·94	Zinc	Zn	64·8
Manganese (Manganium)	Mn	54·8	Zirconium. . . .	Zr	90·48

CHEMICAL AND OTHER MEMORANDA.

The compounds of the non-metallic elements with the metals and with each other have names ending in "ide" or "uret"; as Fe S, sulphide or sulphuret of iron.

When two or more atoms or equivalents of the non-metallic elements enter into combination, the number of atoms or equivalents is expressed by prefixes.

Mon . . . means 1 atom, as N_2 O, nitrogen mon-oxide.

Di, bin, or bi means 2 atoms, as $N_2 O_2$, nitrogen di-oxide, or bin-oxide of nitrogen: CS_2, bi-sulphide or di-sulphide of carbon.

Tri or ter . means 3 atoms, as $N_2 O_3$, nitrogen tri-oxide; $Sb_2 S_3$, ter-sulphide of antimony.

Tetr . . . means 4 atoms, as $N_2 O_4$, nitrogen tetr-oxide.

Pent or penta means 5 atoms, as $N_2 O_5$, nitrogen pent-oxide; PCl_5, penta-chloride of phosphorus.

Sesqui . . means $1\frac{1}{2}$ atoms (=2 to 3), as Fe_2O_3, sesqui-oxide of iron.

Proto or prot means first, as Fe O, prot-oxide of iron.

Sub . . . means under, as Cu_2 O, sub-oxide of copper.

Per . . . means the highest, as H Cl O_4, per-chloric acid.

The terminations "ic" and "ous" are used for acids; the former representing a higher state of oxidation than the latter.

When a substance forms more than two acid compounds, the prefixes "hypo," *under*, and "hyper" *above*, are used.

The smaller number, as H_2, placed to the right of, and slightly below a symbol is called the exponent, and indicates the number of times that the combining weight of the substance has to be taken. When the symbol is without a number—thus, H—the number *one* is understood. The small numbers modify only the symbol immediately preceding, but larger numbers *prefixed* to the symbol modify all that follow as far as the next comma or + sign: thus $2H_2$ SO_4 signifies that four of hydrogen, two of sulphur, and eight of oxygen, or, more correctly, that two of sulphuric acid (H_2 SO_4 being the formula for sulphuric acid) are to be taken.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases, they are said to be hydrated.

Alkalies neutralize acids, forming salts.

Alkalies turn vegetable reds to blue, and yellows to brown.

Acids turn vegetable blues to red, and browns to yellow.

A *simple* or *elementary* substance is a body that cannot be resolved or separated into any simpler substances—as oxygen, carbon, iron.

A *compound* substance is one consisting of two or more constituents —as water, carbonic acid gas, olefiant gas.

The equivalent number or atomic or combining weight expresses the relation that subsists between the different proportions by weight in which substances unite chemically with each other.

The equivalent or combining weight of a compound is the sum of the combining weight of its constituents.

Specific gravity expresses the difference that subsists between the weights of equal volumes of bodies. Gases are usually compared with air as 1·000, liquids and solids with water as 1·000.

So far as chemists have been able to discover, there are about 70 elementary or simple substances.

No compound body contains all the elementary substances. Most compounds are composed of two, three, or four elements.

LIST OF SUBSTANCES

Simple and Compound, frequently mentioned in connection with the Manufacture and Purification of Coal Gas and the Residual Products resulting therefrom.

Name of Substance.	Symbol.
Acetylene	C_2H_2
Ammonia	NH_3
Aniline	C_6H_7N
Aqueous vapour	H_2O
Benzole	C_6H_6
Bisulphide of carbon	CS_2
Bisulphide of iron	$Fe\ S_2$
Butylene	$C_4\ H_8$
Carbon	C
Carbolic acid	C_6H_6O
Carbonate of ammonia	$(NH_4)_2\ CO_3$
Carbonate of lime	$Ca\ CO_3$
Carbonic acid	CO_2
Carbonic oxide	CO
Cyanogen	$C_2\ N_2$
Hydrogen	H
Hydrochloric or muriatic acid	HCl
Light carburetted hydrogen	CH_4
Muriate of ammonia	NH_3HCl, or NH_4Cl
Naphthalene	$C_{10}\ H_8$
Nitrogen	N
Nitric acid	HNO_3

Olefiant gas	C_2H_4
Oxygen	O
Oxide of calcium (caustic lime)	Ca O
Oxide of potassium (caustic potash)	K_2 O
Oxide of sodium (caustic soda)	Na_2 O
Peroxide of iron	Fe_2 O_3
Protoxide of iron	Fe O
Protosulphide of iron . . .	Fe S
Protochloride of manganese .	Mn Cl_2
Propylene	C_3 H_6
Sesquisulphide of iron . .	Fe_2 S_3
Sulphur	S
Sulphate of ammonia . . .	$(NH_4)_2$ SO_4
Sulphide of calcium . . .	Ca S
Sulphuretted hydrogen . .	H_2 S
Sulphuric acid.	H_2SO_4
Sulphur dioxide	SO_2
Water	H_2 O
Weldon Mud	CaO_2, MNO_2

To ascertain the proportion, by *weight*, of the different substances in a compound, multiply the atomic weight of each substance by the exponent.

For example: Take olefiant gas, C_2 H_4, which, as its formula indicates, consists, by weight, of two atoms of carbon combined with four atoms of hydrogen—

Atomic Weight.			Exponent.		Proportion by Weight.	
C	12	×	2	=	24	or 85·715 per cent.
H	1	×	4	=	4	or 14·285 ,,

So that 24 grains, or 24 ounces, or 24 pounds of carbon, combine with 4 grains, or 4 ounces, or 4 pounds of hydrogen to form 28 grains, or 28 ounces, or 28 pounds, and so on, of olefiant gas.

COMMON NAMES OF CERTAIN CHEMICAL SUBSTANCES.

Aqua fortis	Nitric acid.
Aqua regia	A mixture or nitric and hydrochloric acids, so called from its property of dissolving gold.
Bluestone, or blue vitriol	Sulphate of copper.
Bog ore	Oxide of iron.
Calomel	Chloride of mercury.
Chloroform	Chloride of formyle.
Choke-damp	Carbon dioxide.
Common salt	Chloride of sodium.
Copperas, or green vitriol	Sulphate of iron.
Corrosive sublimate	Bichloride of mercury.
Dry alum	Sulphate of alumina and potash.
Epsom salts	Sulphate of magnesia.
Ethiops mineral	Black sulphate of mercury.
Fire-damp	Light carburetted hydrogen.
Galena	Sulphide of lead.
Glauber's salts	Sulphate of soda.
Goulard water	Basic acetate of lead.
Iron pyrites	Bisulphide of iron.
Jeweller's putty	Oxide of tin.
King's yellow	Sulphide of arsenic.
Laughing gas	Protoxite of nitrogen.
Lime	Oxide of calcium.
Lunar caustic	Nitrate of silver.
Mosaic gold	Bisulphide of tin.
Muriate of lime	Chloride of calcium.
Nitre, or saltpetre	Nitrate of potash.
Oil of vitriol	Sulphuric acid.
Potash	Oxide of potassium.
Realgar	Sulphide of arsenic.
Red lead	Oxide of lead.
Rust of iron	Oxide of iron.
Sal ammoniac	Muriate of ammonia.
Soda	Oxide of sodium.
Spirits of hartshorn	Ammonia.

CHEMICAL SUBSTANCES—*Continued.*

Spirit of salt	Hydrochloric or muriatic acid.
Stucco, or plaster of Paris	Sulphate of lime.
Sugar of lead	Acetate of lead.
Tincal	Crude borax.
Verdigris	Basic acetate of copper.
Vermilion	Sulphide of mercury.
Volatile alkali	Ammonia.
Wad	Black oxide of manganese.
Water	Oxide of hydrogen.
White vitriol	Sulphate of zinc.

TABLE OF VARIOUS GASES.

Their Specific Gravity, Weight, and Solubility in Water.

60° Fahr. 30 in. Barometer.

Name.	Specific Gravity. Air equal 1·000	Weight of a Cubic Foot in Pounds Avoirdupois.	Weight of a Cubic Foot in Grains.	Number of Cubic Ft. equal to 1 lb.	Solubility. 100 Vols. of Water absorb.
Hydrogen	·0691	·00529997	37·09	188·68	1·98Vols.
Light carburetted hydrogen	·559	·0428753	300·12	23·32	3·91 „
Ammonia	·590	·045253	316·77	22·09	72,720· „
Carbonic oxide	·967	·0741689	519·18	13·48	2·43 „
Olefiant gas	·968	·0742456	519·71	13·46	16·15 „
Nitrogen	·9713	·07449871	521·49	13·42	1·48 „
Air	1·000	·0767	536·90	13·03	1·70 „
Nitric oxide	1·039	·0796913	557·83	12·54	Notsoluble in water.
Oxygen	1·1056	·08479952	593·59	11·79	2·99Vols.
Sulphuretted hydrogen	1·1747	·09009949	630·69	11·09	323·26 „
Nitrous oxide	1·527	·1171209	819·84	8·53	77·78 „
Carbonic acid	1·529	·1172743	820·92	8·52	100·20 „
Sulphurous acid	2·247	·1723449	1206·41	5·80	4276·60 „
Chlorine	2·470	·189449	1326·14	5·27	236·80 „
Bisulphide of carbon	2·640	·202488	1417·41	4·93	Notsoluble in water.

To reduce a volume of gas of any specific gravity to pounds avoirdupois, multiply the volume by the sp. gr. and by ·0767.

Example.—Required the weight of 1500 cubic feet of gas whose specific gravity is ·520.

$$1500 \times \cdot 520 \times \cdot 0767 = 59{\cdot}826 \text{ lbs.}$$

To find the weight in pounds avoirdupois of a cubic foot of air at different temperatures, and under different pressures.

$$W = \frac{1{\cdot}3253 \times B}{459 + T}$$

Example.—Required the weight of a cubic foot of air, the barometer being at 29·5 inches, and the temperature 84° Fahr.

$$\frac{1{\cdot}3253 \times 29{\cdot}5}{459 + 84} = \cdot 072 \text{ lb.}$$

Luting for Experiments in Chemistry.—For temporarily securing the joints of chemical vessels, glass stoppers, &c., use equal parts by weight of linseed meal and whiting made into a stiff paste with water. The two substances should be well triturated in a mortar, and the water added till of the proper consistency.

Pieces of vulcanized india-rubber tubing are very suitable for joining the ends of glass and earthenware tubes. The india-rubber is slipped over the ends, and secured with pack-thread.

India-rubber capsules for bottle necks, having a hole through them for the insertion of glass tubes are handier, and more likely to be gas-tight, than the ordinary corks.

AVERAGE COMPOSITION OF LONDON GAS BY VOLUME.

(*Dr. Letheby*, 1866.)

Constituents.	Common Gas. Per Cent.	Cannel Gas. Per Cent.
Hydrogen	46·0	27·7
Light carburetted hydrogen	39·5	50·0
Olefiant gas	3·8	13·0
Carbonic oxide	7·5	6·8
Carbonic acid	0·7	0·1
Aqueous vapour	2·0	2·0
Nitrogen	0·5	0·4
	100·0	100·0

(*Professor Vivian B. Lewes*, 1894.)

Constituents.	Gaslight and Coke Company. Per Cent.	South Metropolitan Company. Per Cent.	Commercial Company. Per Cent.
Hydrogen	53·36	52·22	52·96
Unsaturated hydrocarbons	3·58	3·47	3·24
Saturated hydrocarbons	32·69	34·76	34·20
Carbon monoxide	7·05	4·23	4·75
Carbon dioxide	0·61	0·60	0·75
Nitrogen	2·50	4·23	4·10
Oxygen	0·21	0·49	0·00
	100·00	100·00	100·00

TABLE.

Tests made by Professor Vivian B. Lewes, showing the quantity of light obtained per cubic foot of 16-candle gas consumed, proving the advantage of the regenerative and incandescent lights, and the loss which attends the use of ordinary burners.

Burner.	Candle Units.
Regenerative and Incandescent	7 to 10·00
Standard Argand	3·20
Ordinary Argand	2·90
Flat Flame No. 7	2·44
Do. No. 6	2·15
Do. No. 5	1·87
Do. No. 4	1·74
Do. No. 3	1·63
Do. No. 2	1·22
Do. No. 1	0·85
Do. No. 0	0·59

TABLE,

Indicating the Comparative Salubrity of the Several Illuminating Materials.

The flame of coal gas, and the flames of several combustible bodies that gave an amount of light equal to it, were burned separately in given quantities of atmospheric air, and the times were noted at which the flames were extinguished by the contamination of the air. The following were the results :—

Colza oil	was extinguished in	71 minutes
Olive oil	,, ,,	72 ,,
Russian tallow	,, ,,	75 ,,
Sperm oil	,, ,,	76 ,,
Stearic acid	,, ,,	77 ,,
Wax candles	,, ,,	79 ,,
Spermaceti candles	,, ,,	83 ,,
Coal gas	,, ,,	98 ,,
Cannel Gas (28 candles)	,, ,,	152 ,,

From which it appears that the atmosphere of a confined room lighted

by cannel gas will support life twice as long as the atmosphere of the same room lighted equally by tallow candles.

TABLE.

RELATIVE VALUES OF ILLUMINATING AGENTS

In respect of their Heating and Vitiating Effects on the Atmosphere, when Burning so as to give the Light of 12 *Standard Sperm Candles.* (*Dr. Letheby.*)

	Pounds of Water Heated 1° Fahr.	Oxygen Consumed (Cubic Feet).	Carbonic Acid Produced (Cubic Feet).	Air Vitiated (Cubic Feet).
Cannel gas	1950	3·30	2·01	50·2
Common gas	2786	5·45	3·21	80·2
Sperm oil	2335	4·75	3·33	83·3
Benzole	2326	4·46	3·54	88·5
Paraffin	3619	6·81	4·50	112·5
Camphene	3251	6·65	4·77	119·2
Sperm candles	3517	7·57	5·27	131·7
Wax candles	3831	8·41	5·90	149·5
Stearic candles	3747	8·82	6·25	156·2
Tallow candles	5054	12·06	8·73	218·3

TABLE.

Calorific Power of Various Photogenic Compounds. (*F. J. Evans.*)

Name of Gas, &c.	Cubic Feet to One Pound.	Pounds of Water raised 1° by the Consumption of 1 Foot of Gas.	Pounds of Water raised 1° by the Consumption of 1 lb. of Gas.
Hydrogen	180·0	300	54,000
Newcastle coal gas, sp. gr. ·410	32·4	650	21,060
Cannel gas, sp. gr. ·500	26·5	760	20,140
Oil gas, sp. gr. ·825	16·69	1200	20,028
			1 lb. of candles.
Sperm candles, 6 to the lb.			17,567
			1 lb. of oil.
Sperm oil, burnt in a lamp			16,490

TABLE.

Combustion, Temperature, Explosive Power, and Mechanical Power of Gases. (LETHEBY).

Name.	Per lb. Substance.			Pounds Water Heated 1° Fahr.			Temperature of Combustion.				Explosive Power.		Mechanical Power per lb.
							Open Flame.		Closed Vessel.				
	Ox. Used.	CO_2 Produced.	Air Vitiated.	Per lb. Substance.	Per Cubic Foot Substance.	Per lb. Ox. Used.	With Ox.	With Air.	With Ox.	With Air.	With Ox.	With Air.	Tons Raised 1 Foot High.
	Cubic Feet.	Cubic Feet.	Cubic Feet.	Lbs.	Lbs.	Lbs.	Deg.	Deg.	Deg.	Deg.	Atmospheres.	Atmospheres.	Tons.
Hydrogen	93·4	0·0	467	62,030	329	7,754	14,510	5,744	19,035	7,852	25·6	12·5	21,390
Marsh gas	47·2	23·6	826	23,513	996	5,878	14,130	4,762	18,351	6,680	37·0	14·0	8,108
Olefiant gas	40·5	27·0	878	21,344	1,585	6,225	16,535	5,217	21,344	7,200	42·9	15·1	7,360
Propylene	40·5	27·0	878	21,327	2,376	6,220	16,522	5,239	21,327	7,177	67·3	22·5	7,360
Butylene	40·5	27·0	878	21,327	3,168	6,220	16,522	5,232	21,327	7,177	85·8	30·2	7,360
Acetylene	36·3	29·1	909	18,197	1,251	5,914	17,146	5,142	22,006	7,009	87·9	17·6	6,275
Benzole	36·3	29·1	909	18,197	3,860	5,915	17,146	5,142	22,006	7,009	113·7	52·8	6,275
Carbonic oxide	6·7	13·5	371	4,325	320	7,569	12,719	5,358	16,173	7,225	21·8	11·7	1,490
Bisulphide carbon	14·9	5·0	689	6,120	1,239	4,845	15,280	4,814	20,031	5,917	30·2	11·6	2,110
Sulph. hydrogen	16·7	0·0	630	7,444	671	5,271	13,688	4,388	17,542	6,026	28·3	12·7	2,567
Cyanogen	14·5	14·5	435	6,712	925	5,142	13,488	5,028	17,645	6,167	35·6	17·8	2,314
Common coal gas	37·5	17·6	618	21,060	650	6,816	14,320	5,228	18,101	7,001	29·2	14·6	7,262
Cannel gas	31·0	22·0	698	20,140	760	6,503	14,826	5,121	19,046	7,186	38·8	18·0	6,945
Wood spirit	25·3	11·8	422	9,547	819	6,363	11,435	4,641	14,902	6,847	40·3	15·3	3,290
Alcohol	24·6	16·4	533	12,929	1,597	6,195	13,305	4,831	17,223	6,629	46·4	16·1	4,455
Ether	30·9	20·4	664	16,249	3,217	6,158	14,874	5,150	19,225	6,953	58·6	19·0	5,603
Camphine	38·9	27·8	880	19,573	7,134	5,942	16,271	5,026	20,953	6,922	47·6	16·0	6,750
Spermaceti	37·0	25·2	815	17,589	..	6,088	14,599	4,413	..	..	..	..	6,065
Wax	37·7	25·6	829	15,809	..	4,995	12,921	4,122	..	..	..	..	5,451
Stearic acid	34·6	24·0	783	17,050	..	6,061	15,885	4,818	..	..	..	..	5,880
Stearin	34·4	14·2	527	18,001	..	6,143	15,815	5,095	..	..	..	..	6,207
Paraffin	40·5	27·0	878	21,327	..	6,220	16,522	5,239	..	..	..	..	7,354
Paraffin oil	40·5	27·0	878	21,327	..	6,220	16,522	5,239	..	..	..	..	7,354
Rape oil	38·7	24·3	801	17,752	..	6,123	15,830	5,087	..	..	..	..	6,121
Sperm oil	38·7	24·3	801	17,230	..	6,088	15,363	4,937	..	..	..	..	5,941
Carbon	31·0	31·5	943	14,544	..	5,447	18,329	3,026	..	..	..	..	5,015

TABLE.

Heats of Combustion with Oxygen.

Substance.		British Thermal Units of Heat.	Pounds of Water at 212° Fahr. Evaporated per Pound of Substance.
Hydrogen		61,500	63·66
Alcohol		12,963	13·42
Benzene		18,600	19·25
Carbon bisulphide		6,152	6·37
Carbon burning to carbonic acid		12,906	13·36
Carbon burning to carbonic oxide		2,495	2·58
Carbonic oxide burning to carbonic acid		4,478	4·63
Charcoal, wood		12,455	12·90
Coal, anthracite		15,600	16·14
Coal, best bituminous		15,504	16·05
Coke, produced from ditto		14,375	14·88
Coal, average quality		13,600	14·08
Coke, produced from ditto		12,800	13·25
Ethylene		21,500	22·25
Graphite		14,067	14·56
Light carburetted hydrogen, or marsh gas		24,020	24·86
Lignite		11,710	12·12
Olefiant gas		21,375	22·12
Olive oil		17,784	18·41
Peat, dry		9,983	10·33
Petroleum		20,272	20·98
Propylene		21,200	21·94
Sulphur		4,032	4·17
Sulphuric ether		16,282	16·85
Turpentine		19,566	20·25
Wood, dry		7,824	8·10
	Cubic Feet per lb.		
Coal gas, 17 candles	32·227	21,696	22·46
Water gas	22·862	6,649	6·88
Producer gas	14·369	1,897	1·96
Producer water gas	13·478	983	1·02

The British standard unit of heat (thermal unit) is the amount of heat required to raise the temperature of 1 lb. avoirdupois of water 1° Fahrenheit.

The French standard unit of heat (calorie) is the amount of heat required to raise the temperature of 1 kilogramme of water 1° Centigrade.

The number of British units of heat required to evaporate 1 lb. of water at boiling point, 212° Fahr., is 966; and at 62° Fahr., 1116.

The number of French units of heat required to evaporate 1 kilo. of water at boiling point, 100° Cent., is 536·7; and at 16·6° Cent., 620·1.

One British unit of heat = ·0251996 French units.

One French unit of heat = 3·96832 British units.

The total heating power of any fuel, expressed in British units, ÷ 966 = lbs. of water at 212° Fahr. evaporated per lb. of fuel.

EXAMPLE:—1 lb. of hydrogen yields in combustion 61,500 units of heat.

Then:— $\frac{61,500}{966}$ = 63·66 lbs. of water at 212° Fahr. evaporated per lb. of hydrogen.

DISTILLED WATER.

(At 62° Fahr.)

1 pint = 34·65 cubic inches, or 1·25 lbs.
1 gal. = 277·274 cubic inches, or 10 lbs.
11·2 gals., or 1·792 c. feet = 1 cwt.
224 gals., or 35·84 c. feet = 1 ton.
1 cubic inch = 252·45 grs. or ·036075 lb.
12 ,, inches = ·434 lb.
1 ,, foot = 6·25 gals., or 1000 ozs., or 62·5 lbs.
1·8 ,, ,, = 1 cwt.
35·84 cubic feet = 1 ton.
1 cylindrical inch = ·02842 lb.
12 ,, inches = ·341 lb.
1 ,, foot = 5 gals., or 49·1 lbs.
2·282 ,, feet = 1 cwt.
45·64 ,, ,, = 1 ton.

Centre of pressure ⅔ depth from surface.

Water is at its maximum density at 39·2° Fahr. (4° C.), and expands 1-10th part of its bulk on freezing.

SPECIFIC HEAT OF SUBSTANCES.

The meaning implied in the term "specific heat," or more correctly "calorific capacity," is the quantity of heat required to raise the temperature of a substance 1° (independently of the unit of mass and scale of temperature); water being taken as the standard of comparison.

For example: the specific heat of mercury is ·03332, by which is to be understood that thirty times as much heat is required to raise water to a given temperature as an equal weight of mercury. In other words, the quantity of heat which would raise the temperature of any given weight of mercury through 1°, would only raise the temperature of a like weight of water through ·03332°.

SPECIFIC HEAT OF SOLIDS AND LIQUIDS.

(Water as 1.)

Acetic acid	·6589	Lead	·0314
Alcohol (sp. gr. ·793)	·622	Lime, burned	·217
Aluminium	·2143	Lithium	·9408
Antimony, cast	·05077	Magnesium	·2499
Arsenic	·0814	Manganese	·1217
Bees-wax	·45	Marble, white	·21585
Benzine	·3952	Mercury	·03332
Birch	·48	Nickel	·10863
Bismuth	·03084	Oil, olive	·3096
Brass	·09391	Oil, sweet	·31
Brick, common	·2	Oil of turpentine	·472
Brick, fire	·22	Palladium	·05928
Cadmium	·05669	Phosphorus	·18949
Chalk, white	·21485	Pine	·65
Charcoal, animal, calcined	·26085	Platinum	·03243
Charcoal, wood	·24111	Potassium	·1696
Clay, white, burned	·185	Selenium	·07616
Coal	·2777	Silicon, crystallized	·1774
Cobalt	·10696	Silicon, fused	·175
Copper	·09215	Silver	·05701
Diamond	·14687	Sodium	·2934
Ether	·5207	Spermaceti	·32
Glass	·19768	Steel	·1175
Gold	·03244	Sulphur	·20259
Graphite	·20187	Sulphuric acid	·333
Ice	·504	Tellurium	·04737
Iodine	·05412	Thallium	·0336
Iron, cast	·12983	Tin	·05695
Iron, wrought	·11379	Zinc	·09555

SPECIFIC HEAT OF GASES AND VAPOURS.

		Specific Heat of Equal Weights.	Specific Heat of Equal Volumes.	Specific Heat of Constant Volumes.
Simple gases.	Air	0·2374	0·2374	0·1687
	Oxygen	0·2175	0·2405	0·1559
	Nitrogen	0·2438	0·2370	0·1740
	Hydrogen	3·4090	0·2359	2·4096
	Chlorine	0·1210	0·2962	—
Vapour.	Bromine	0·0555	0·3040	—
Compound gases.	Binoxide of nitrogen	0·2315	0·2406	—
	Carbonic oxide	0·2450	0·2370	0·1768
	Carbonic acid	0·2163	0·3307	0·1714
	Sulphuretted hydrogen	0·2432	0·2857	—
	Sulphurous anhydride	0·1553	0·3414	0·1246
	Hydrochloric acid	0·1845	0·2333	—
	Nitrous oxide	0·2262	0·3447	—
	Nitric oxide	0·2317	0·2406	—
	Ammonia	0·5083	0·2966	—
	Marsh gas	0·5929	0·3277	0·4683
	Olefiant gas (ethylene)	0·4040	0·4106	—
	Water (steam)	0·4805	0·2984	0·3337
Vapours.	Ether	0·4810	1·2296	0·3411
	Chloroform	0·1567	0·6461	—
	Alcohol	0·4534	0·7171	0·3200
	Turpentine	0·5061	2·3776	—
	Bisulphide of carbon	0·1570	0·4140	—
	Benzole	0·3754	1·0114	—
	Acetone	0·4125	0·8244	—

TABLE,

Showing the Expansion of Liquids in Volume from 32° to 212° Fahr.

1000 parts of water	become	1046
„ oil	„	1080
„ mercury	„	1018
„ spirits of wine	„	1110
„ air	„	1373 to 1375

TABLE,

Showing the Lineal Expansion of Metals produced by Raising their Temperature from 32° to 212° Fahr.

Zinc	1 part in 322	Gold	1 part in 682
Lead	„ 351	Bismuth	„ 719
Tin (pure)	„ 403	Iron	„ 812
Tin (impure)	„ 500	Antimony	„ 923
Silver	„ 524	Palladium	„ 1000
Copper	„ 581	Platinum	„ 1100
Brass	„ 584	Flint glass	„ 1248

TABLE,

Showing the Relative Power of Metals for Conducting Heat.

Gold	1000	Iron	374·3
Silver	973	Zinc	363
Copper	898·2	Tin	303·9
Platinum	381	Lead	179·6

TABLE,

Showing the Relative Power of Metals for Reflecting Heat.

Intensity of Direct Radiation, 100.

Silver plate	·97	Polished platinum	·80
Gold	·95	Steel	·83
Brass	·93	Zinc	·81
Speculum metal	·86	Iron	·77
Tin	·85		

TABLE.

Melting Points.

	Degrees Fahr.		Degrees Fahr.
Aluminium	1247	Phosphorus	111
Antimony	797	Platinum	3227
Bismuth	504·94	Potassium	136·4
Bronze	1652	Silver	1832
Butter	91	Sodium	203 to 204·08
Copper	2102	Spermaceti	120
Gold	2192	Stearine	131
Ditto, coined	2156	Steel	2372 to 2552
Ice	32	Sulphur	230
Iodine	237·5	Tin	549
Iron, cast	1922 to 2382	Wax, white	154
Ditto, wrought	2732 to 2912	Ditto, yellow	144
Lead	617	Zinc	786·2

THE GAS INDUSTRY.

Initiation, Development and Progress.—The manufacture and distribution of coal gas may be justly described as one of the important industries of the world. Like railways and the electric telegraph, it is a product of the 19th century; for, though coal gas was actually used for illuminating purposes by William Murdoch, the inventor of gas lighting, as early as 1792, at Redruth, in Cornwall, and in 1797 at his house at Old Cumnock, Ayrshire, it was not until well into the first decade of the present century that gas began to be generally applied in the lighting of streets, factories, and dwelling-houses.

The illumination of the Soho Works, Birmingham, to celebrate the Peace of Amiens, took place in 1802. These works belonged to Boulton and Watt, and Murdoch was employed as manager to the Firm. The first application of gas to the interior lighting of large premises was made by Murdoch in Salford, in 1805, at the cotton manufactory of Phillips and Lee; and the first street lighted with gas was Pall Mall, London, in 1807. The first gas Company incorporated by Act of Parliament was the "Chartered" (now the Gaslight and Coke), London, in 1812.

Although in its earliest use coal gas was restricted to the purpose of affording artificial light, no long time elapsed before its value as a heating medium began to be realized. Winsor, one of the pioneers of gas lighting, claimed as an important advantage of the new invention or discovery that gas, besides its light-giving qualities, could be used both for cooking food and warming dwellings, and as early as 1825 attempts were made to apply it for these purposes. It was not, however, till later on in the century that anything like a practical application of gas was made to the cooking of food. Mr. J. Sharp, of Southampton, about the year 1840, began to construct ovens heated by gas for cooking and baking, and these he used for many years, giving public lectures, in the course of which he practically demonstrated their usefulness and value.

Gas, however, in those days was higher in price than now; and, although it was evident that it served most efficiently for culinary operations, its cost militated against its extensive adoption in this direction. The prejudice against it was strong, also, on account of the supposed liability of any food cooked by its means to be tainted with the flavour of the gas itself. This operated against its use; and though

the prejudice was founded on ignorance of the facts, it is not a matter of wonder that such an idea was entertained, seeing that, even at the present day, in spite of the strongest evidence to the contrary, the same belief is still widely accepted, and still operates with many as a bar to its adoption.

Gas has won for itself an important place as an agent for obtaining motive power. It was from the very first a matter of observation, and not unfrequently of dire and unsought experience, that when gas and atmospheric air were mixed in certain proportions, and the mixture fired, an explosion was the result. Attempts were soon made to utilize the force thus exerted by confining the explosive compound in a suitable cylinder, and exploding it to obtain prime movement as in the steam engine. After many more or less successful attempts by different inventors, and the expenditure of much ingenuity, the 'Lenoir" gas-engine, so named after its inventor, was produced (1860), and thus was solved the problem of how to utilize an explosive mixture of gas and air as a prime motor. From that time down to the present the patent records contain the description of many inventions of this character, and gas-engines of great power and efficiency are now produced.

It is occasionally a subject of remark by uninformed or hostile critics, that no important improvements have been effected in gas manufacture since the earlier days of its introduction. If this were so, it would either speak well for the inventors of this art, or badly for their successors in the industry. The statement, however, is altogether wide of the truth. True, the method of producing the gas, as in the earlier days, is by distillation of the coal in closed retorts, and the purification, storage, and distribution of gas are effected in apparatus and plant which, in their main features, do not greatly differ from the earlier forms. But it is obvious that a similar invidious comparison might be made in regard to all the most notable inventions. The chief characteristics of an industry are retained, whilst the processes undergo improvement and modification. As a matter of fact, great improvements have been effected in the plant and apparatus for the manufacture of illuminating gas, whilst the mechanical and chemical principles involved in its production and use are now carefully investigated by gas engineers, and are yearly becoming better understood.

Illuminating Power.—In England, Wales, and Ireland the gas

actually supplied to consumers varies in illuminating power from 14 to 22 standard candles, according to the quality of the coal used; the higher figure above 16 candles being obtained by an admixture of cannel, or shale, with the ordinary bituminous coal, or the use of oil as an enricher. In Scotland the range of illuminating value is from 22 to 30 candles.

Cost Price.—The average cost of producing and distributing illuminating gas in England is about two-thirds of the selling price. Taking a selling price of, say, 2s. 6d. per 1000 cubic feet, the cost of producing and distributing the gas, including the net expenditure on coal (after deducting the income from residuals) and working expenses, will be 1s. 8d. per 1000 cubic feet. Analyzing this figure, the expenditure on coal will be 1s. 3d., and deducting the value of the residuals, at present prices, which is equal to 7d., there is left 8d. as the net cost of the coal. The balance of 1s. 1d. is made up by the working expenses, which include wages, salaries, purifying materials, repairs and renewals, rates and taxes, printing and stationery, and incidental expenses. The difference of 10d. between the prime cost of the gas, 1s. 8d., and its selling price of 2s. 6d. is absorbed in the payment of the interest and dividend on the invested capital in the case of a Company, and in the instance of the Undertaking belonging to a Local Authority, in the discharge of the interest on the annuities and borrowed capital (if any), and the provision of a sinking fund.

Selling Price.—The selling price of gas per 1000 cubic feet ranges throughout England, Wales, and Ireland from 1s. 6d. to 6s., and in Scotland from 3s. to 8s. 4d., with a few of the smallest concerns charging as much as 10s. per 1000 cubic feet. Taking into consideration, however, that in Scotland gas of a higher illuminating power is supplied than in the other portions of the kingdom, that a smaller consumption per consumer is the consequence, and calculating the price at per theoretical unit of light, the actual difference in price is not so great as appears at first sight. The practical advantages, however, of the higher illuminating powers may be questioned, and certainly they are not proportionate to the cost of producing the richer gas.

Capital Employed.—The Capital of a Gas Undertaking represents or includes (1) the amount of money that has been expended on obtaining an Act of Incorporation, if it be a Statutory Company; (2) the cost of the land for the site of the works, and the engineering expenses incurred; (3) the cost of the general manufacturing,

purifying and storing plant; and (4) the cost of the distributing pipes and accessories; with (5) an added sum as a floating or working capital to meet current outlay before the revenue begins to accrue.

The amount of the various items making up the aggregate, necessarily varies under different conditions. For example, take the first—the money expended on obtaining an Act of Incorporation. When a Company have had to contend with and overcome persistent and strong opposition, the cost of their Act will exceed the cost of one obtained under more favourable conditions, to the extent of 100, 200, or even 300 per cent. Again, the cost of land is a varying factor, and the expense of the erection of works is often increased by the character of the site and its subsoil. It is true that in the case of a large Company, these several items, even when greatly in excess of a normal amount, do not increase the total capital outlay by any material percentage; but on small and moderate-sized undertakings they are often peculiarly burdensome.

But there are other circumstances more distinctly marked than these, which contribute to the variations in the relative amount of capital expended by different Companies. The character of the district of supply is one of them. The district of some Companies is thickly populated with a high class of consumers throughout. Others, again, have a scanty population, and of a poorer class; and although the plant and mains of this latter may be less extensive, yet the proportion of its capital to the production and rental will usually be in excess of the other, whilst there is this paradoxical result in the instances referred to, that those who are least able to afford it have often necessarily to pay a higher price for the gas.

In many instances, Companies have wide expanses of country to canalize with miles of mains, on some of which, except at the terminus, there is scarcely a consumer. Again, the district may be a manufacturing one, with mills and workshops consuming gas only during four or five months in the year. The proportion of capital in such case has frequently to be large to provide plant to meet the principal gas demands within a limited period of time. It is no unusual thing, under such circumstances, to find that during nearly one half of the year, seven-tenths of the whole plant is standing unproductive.

In contrast to these, there are towns whose gas consumption is comparatively steady all the year round. Take, as an example, the inland watering-places and fashionable sea-side towns. Into these,

there is during the summer and autumn seasons, an influx of visitors who consume a large quantity of gas. Such is proved by the fact that the heaviest daily make in these places is generally in the months of August, September, or October. This tends to equalize the consumption in the different seasons, because the resident inhabitants consume their proportion of gas during the winter and early spring months, when the visitors are absent. It is fair to conclude that, owing to this regular and steady consumption, the plant is almost continuously employed, and therefore a smaller capital in proportion to the yearly production is required than in those places where the heavy consumption is spasmodic and brief.

But although this spasmodic consumption appears, at first sight, a serious drawback, in practice it does not always necessitate a higher price for the gas, and a much larger capital outlay than is required by those concerns whose consumption or sale of gas is steadier; for in some of the large manufacturing towns the mill consumption is so enormous that, by straining the plant for limited periods, the disadvantage is counterbalanced.

There can be no question that expensive engineering tends to an undue inflation of the capital account. A want of engineering skill in the construction of works has precisely the same effect; for here, as in other matters, extremes meet.

Considerable thought will always be given by a capable and conscientious engineer to the proper arrangement of works. He will so perfect his designs that the works shall not be squandered or sprawling over the site, occupying unnecessary space, but compact and harmonious, so that the different processes in gas making may be conveniently carried on, and economical in the working.

Whilst it is not necessary or desirable that the buildings of a gas-works should be as strong as a castle, it is equally objectionable to set up unstable and flimsy structures that entail an annual heavy expenditure for repairs, constituting a perpetual tax, enhancing the cost of working.

Excessive and unnecessary ornamentation is to be eschewed in all works of this kind. All ornamentation, however, is not useless. Blank thick walls, for example, are not necessarily stronger than others well proportioned—thinner and lighter in parts, but strengthened by suitable projections that add to the beauty of a building by breaking the dull uniformity. The same argument holds good as respects design in apparatus. Taste should not be neg-

lected; and there is ample scope for the exercise of good taste in most departments of a gas-works.

On a closer examination of the question, it will be apparent that there occur times in the history of most gas undertakings when the capital expenditure is either below or in excess of the average, viz.—when the margin of its producing, storing, and distributing resources is closely worked up, and enlargement is required, then the capital compared with the production is low. But extensions have to be carried out. These must necessarily be of such extent as to provide a margin for future increased consumption, and, being larger than the immediate requirements of the district, the capital is swelled out of proportion. This is especially true of times when trade is brisk, and labour and materials are dear. Then extensions are costly, and, singular to say, it is at such times that they are most frequently made. Under such circumstances, unless resort can be had to a reserve fund to maintain the dividends, a sacrifice of a portion of the statutory interest has to be submitted to or the price of the gas increased.

But this condition of things is by no means inevitable. One of the evidences of good administrative skill in the conduct of a gas-works is the ensuring that extensions are carried out systematically and with foresight, and in as gradual a manner as may be, not postponing them to the very last extremity; in other words, starving the concern—wearing it threadbare—which is the worst policy possible for the undertaking and all associated with it, including both shareholders and consumers.

The capital of gas-works in the hands of Corporations and other Local Authorities is, as a rule, in excess of that of Companies; but this arises from causes well understood. Many towns' Authorities have within comparatively recent years become possessed of gas-undertakings by purchase from the Companies who previously owned them; and, as in most cases they have had to pay the full market price for the concern, amounting to from twenty to twenty-eight years' purchase of the annual profits, and even more in some instances, the result is that the capital outlay is large—with this compensatory advantage, however, that the percentage of interest to be paid on such capital is not more, but usually less, than that paid by the Company on the smaller capital. As time goes on, and extensions of the Corporation works are made, these are carried out with an expenditure, though not necessarily less than that of a Company, yet

bearing a lower rate of interest, and consequently pressing less heavily on the resources of the undertaking.

But this remark needs qualification. In the case of Local Authorities becoming possessed of such works, a sinking fund has to be provided out of the profits to redeem the capital within a given period. Fifty years was formerly a usual term to allow; but there is a tendency (especially on the part of the Local Government Board), to restrict the term to thirty and even twenty years. The result is that the annual charge for interest and sinking fund is in excess of the rate at which a Company under the Auction Clauses can raise its additional capital. True, the sinking fund eventually wipes out the capital liability, and the present generation of overburdened consumers have to be consoled by the knowledge that posterity will reap the benefit of their self-sacrifice.

The immediate effect of an excessively large capital outlay by a Gas Company is, as has been already remarked, either a sacrifice by the shareholders of a proportion of the statutory dividends, or an augmentation in the selling price of the gas; and not unfrequently, when the capital is greatly in excess, both these undesirable results are experienced.

One of the best, perhaps the very best method of reducing the proportion which capital expenditure bears to revenue, is to cultivate a day consumption of gas, by affording facilities for, and encouraging in every legitimate way the use of gas for cooking, heating, and motive power. This policy, if pursued to a successful issue, is virtually to reduce the percentage of capital in the proportion of such consumption, because the plant is brought to bear in earning profit during the daylight as well as in the lighting hours.

It is unreasonable to expect that the capital of Gas Companies, and the selling price of gas, can ever be uniform throughout the country. It would be just as reasonable to expect that the general rates of different districts can be equalized. All the causes above pointed out, and others not touched upon, militate against such a result.

The "Auction Clauses."—These clauses, which are now, and for many years past have been, introduced into the Bill of every Gas Company making application to Parliament for money powers, are, without doubt, an ingenious and fairly satisfactory device for securing the economization of capital.

They provide that the additional stock or share capital required

shall be raised by public auction or tender, instead of, as formerly, by the allotment of the stock or shares to the existing shareholders *pro rata* at par.

The immediate result of this is that there is no inducement to the Company to issue and expend more capital than is, from time to time, absolutely necessary.

A limited amount of ordinary stock is put up to competition, and this bearing, say, a seven per cent. standard dividend, commands (in a well-managed Company) a premium in the market of at least 50 per cent. In other words, £100 par value of stock or shares sells for, say, £150, being thus sold and bought to yield about 4 to $4\frac{3}{8}$ per cent. interest.

The 50 per cent. or whatever premium is realized, forms part of the capital for extensions of works, but is not entitled to dividend. In this way the importation of non-dividend bearing capital into the concern is advantageous to the general body of consumers, whilst at the same time it tends to give stability to the undertaking.

The "Sliding Scale."—This is not inserted compulsorily in Gas Bills, as are the auction clauses, but at the option of the Company applying to Parliament. A standard selling price for the gas, and a standard rate of dividend being given, it is provided that for every penny of a reduction in the price of the gas below the standard, the Company are empowered to pay a quarter per cent. above the standard dividend, or one per cent. for a reduction of fourpence, and *vice versâ*, if the selling price of the gas is raised.

It is assumed, though it is by no means always the case, that the margin of profit earned after making the reduction, is sufficient to allow of the increased dividend to which the shareholders are entitled; otherwise, of course, it cannot be paid, unless there is a balance in hand of revenue that can be drawn upon.

The effect of the sliding scale is to confer a greater benefit on the consumers than on the shareholders; because a reduction of a penny per 1000 cubic feet on the total quantity of gas sold often amounts to a sum four times larger than that represented by the additional quarter per cent. dividend to which the shareholders are entitled by reason of the reduction. In point of fact, the sliding scale creates a virtual partnership between the gas consumer and the gas proprietor, to the advantage of the former.

The combined effect of the auction clauses and the sliding scale has

been to induce the exercise of economy, both in the expenditure of capital and in the general working of the undertaking, and so to secure a gradual reduction in the selling price of the gas.

No doubt the Companies who were enabled to adopt the sliding scale of price and dividend in the early days of its inception, are to be congratulated on the results they have achieved in the way of enhanced dividends by its application and working; but there is less room for congratulation to any who adopt it now, with the closer limitations which prevail in fixing the initial or standard price.

It is clear, also, that Companies seeking powers at a time when coal and materials generally are low in price, are placed at a disadvantage as compared with other Companies applying to Parliament in a time of inflated prices. Notwithstanding all experience, one of the ruling characteristics of average human nature is to conclude that that which actually exists will scarcely ever again be modified to any large extent. Injustice may, therefore, unintentionally, be meted out to one Company, and more than justice to another; and so, when the reaction comes, the circumstances of the first suffer impairment, whilst the other is glutted with a run of good fortune. This want of equal justice in the incidence of the sliding scale, whilst inevitable, is sufficient to convince any disinterested observer that its indiscriminate advocacy is a mistake. It is, moreover, a curious and interesting commentary on the action of the sliding scale that, in spite of the inducement which it offers for a low selling price, there are both Gas Companies and Local Authorities who, without it, can produce and sell gas at a price as low as, or even lower than, those who boast its possession.

Sundry Useful Notes.—In choosing the site for a gas-works, consideration should be had to its position, which should be at the lowest, or nearly the lowest, part of the district, to obtain the advantage of the natural increase in the pressure of the gas in travelling to the higher levels.

It should, if possible, be alongside a railway, navigable river, or canal, for convenience in the delivery of coal and other materials, and the disposal of such of the residuals as are despatched to a distance.

The buildings and plant should be so set out on the land as to admit of future extensions being made with ease and economy.

The design of a structure should be in keeping with the purpose for which the structure is intended.

The term "Structural Value" has reference to the amount of capital expended upon works in their construction.

"Commercial Value" is the value of the net annual profits which a Firm or Company can make by the use of their works.

Capital is best spent on substantial tanks and apparatus. Mere ornament should be a secondary consideration.

The average cost of gas-works in provincial towns is about £1 per head of the population. In very large towns it will amount to more, and in very small towns it will scarcely reach that sum.

The capital of most gas-works per million cubic feet of gas produced per annum is from £500 to £700; or at the rate of about 10s. to 14s. per 1000 cubic feet. Reckoned on the *maximum* production of gas in 24 hours, the capital will amount to about 2s. 8d. to 2s. 8d. per cubic foot, or, say, £112 to £138 per 1000 cubic feet.

The capital of a well-managed Gas Company of average size, does not usually amount to more than four times the annual gas rental. *Vice versâ*, the gas rental should be at least one-fourth of the capital.

The population per mile of main is usually about 2000 people. In densely populated towns it will rise to 3000; but in fashionable residential places, where the houses stand more apart, the population per mile of main will fall below 1000.

The usual consumption of gas per mile of main in large towns ranges from 2½ to 5 millions of cubic feet per annum; and in small towns from 2 to 3 millions.

The gas rental per mile of main usually ranges from £400 to £600 per annum.

The average consumption per head of the population in large towns is about 2000 cubic feet per annum; in small manufacturing towns about 1600 cubic feet, and in agricultural towns about 1000 to 1200 cubic feet per annum.

The usual annual increase in the consumption of gas is from 5 to 10 per cent. In rapidly growing districts it will range higher.

TABLE,

Showing the Time in which the Yearly Consumption of Gas will be Doubled, at Different Annual Rates of Increase.

Rate per cent. of Increase per ann.	Time in which the Consumption will be Doubled.	Rate per cent. of Increase per ann.	Time in which the Consumption will be Doubled.	Rate per cent. of Increase per ann.	Time in which the Consumption will be Doubled.
2	35 years, 1 day.	5½	12 years, 345 days.	9	8 years, 16 days.
2½	28 years, 26 days.	6	11 years, 327 days.	9½	7 years, 283 days.
3	23 years, 164 days.	6½	11 years, 2 days.	10	7 years, 100 days.
3½	20 years, 54 days.	7	10 years, 89 days.	10½	6 years, 344 days.
4	17 years, 246 days.	7½	9 years, 213 days.	11	6 years, 234 days.
4½	15 years, 273 days.	8	9 years, 2 days.	11½	6 years, 134 days.
5	14 years, 75 days.	8½	8 years, 181 days.	12	6 years, 42 days.

Handy Rule for Converting Capital per Million Cubic Feet into Capital per Thousand Cubic Feet.

Point off all the figures after the hundreds as decimals, and multiply by two.

EXAMPLE.—The capital of a gas undertaking is £625 per million cubic feet of gas sold (or produced) per annum, what is the capital per 1000 cubic feet?

THEN.—$6 \cdot 25 \times 2 = 12 \cdot 50$; say, 12s. 6d. per 1000 cubic feet.

GOLDEN RULES FOR GAS MANAGERS.

Keep up the heats of the retorts.

Keep up the efficiency of the meters.

Keep down the pressure in the mains.

Keep down the arrears in the gas ledger.

These rules are as applicable to-day as they were on the first day they were penned, as they embody all the philosophy of gas management. A strict adherence to the advice which they give will ensure the success of any gas undertaking, just as a disregard of them will result in loss and disaster.

It has been attempted (with little success, and less reason) to impugn the utility of the third rule. To keep down the pressure in the daytime is, it is alleged, to discourage the use of gas for cooking and

heating. But, surely, to make such a remark is to betray an amount of dulness not easy to understand. The meaning of the rule is obvious. It is not advised that the pressure should be kept down to an abnormal extent. Whatever pressure is required either by day or night must, of course, be maintained; the rule indeed implies as much, but it implies something more—its object is to discountenance the maintenance of a *wasteful* pressure, and all pressure in excess of actual requirements is wasteful. *Verbum sat sapienti.*

COEFFICIENTS

OF THE

Number, Dimensions, and Cost of the various Buildings, Apparatus, Machinery, and Plant of a Gas-Works.

It is an almost impossible task to give a series of coefficients of the number, dimensions, and cost of Buildings, Apparatus, Machinery, and Plant, applicable to the individual case of every Gas-Works in the United Kingdom. That such is the fact will be clear when the variations in size, character of subsoil, design (whether substantial or otherwise), and situation of such Works, are taken into consideration.

Again, although the cost based on the prices of labour and materials ruling at the present time may be applicable, it is evident that the figures will necessarily vary with the fluctuations in the market prices, and the effect of competition.

And neither is it possible to fix with perfect accuracy a standard of prices as a basis that will apply even under existing circumstances, as such prices vary, less or more, in different parts of the country.

At the best, it is only an approximation that can be given, and an attempt in this direction is made as follows:—

Prices on which the Coefficients of Cost are based.

Labour.	Average.
Skilled labour	10d. per hour.
Unskilled ditto	4d. to 6d. per hour.
Bricksetting, labour only	1s. 3d. per sq. yd. 9″ thick.
Retort setting, labour only	22s. per mouthpiece.

Materials.	Average.
Selected best pressed bricks	£2 to £2 5s. per 1000.
Common bricks, best	20s. per 1000.
Portland cement	50s. per ton.
Lias or hydraulic lime	22s. ditto.
Ordinary lime	12s. ditto.
Building sand	1s. per load.
Sheet lead for flashing	18s. 6d. per cwt.
Fire-bricks	60s. per 1000.
Superior refractory bricks, as silica, &c.	85s. ditto.
Fire-clay, ground	20s. per ton.
Clay retorts 21" × 15"	4s. per lineal foot.
Cast-iron pipes 2" to 4" diameter	£5 5s. per ton.
Ditto 5" to 8" „	£5 ditto.
Ditto 9" to 16" „	£4 15s. ditto.
Ditto 17" and upwards	£4 12s. ditto.
Specials, cast-iron	£8 to £11 ditto.

The cost of laying and jointing pipes is given on pp. 217 and 218.

Wrought-iron tubes according to list prices, with 60 per cent. discount.

Ditto fittings ditto.

Labour and Materials combined.	Average.
Stock brickwork, 9" thick	5s. 6d. per square yard.
Common ditto, best, 9" thick	3s. 9d. ditto.
Superior dressed stonework	3s. per cubic foot.
Rubble ditto	10s. per cubic yard.
Slating	3s. to 3s. 6d. per square yard.
Flagging, 3" flags	3s. 6d. to 5s. ditto.
Paving with 5" and 6" setts	3s. 6d. to 5s. ditto.
Portland cement concrete 1 in 9	10s. per cubic yard.
Ditto ditto 1 in 7	12s. ditto.
Ditto ditto 1 in 5	14s. ditto.
Cast-iron in large castings	£7 10s. per ton.
Ditto ditto fixing only	15s. ditto.
Ditto small castings	£10 to £12 ditto.
Plain cast-iron columns and beams	£7 5s. to £7 15s. ditto.
Ditto ditto fixing only	10s. to 15s. ditto.
Steel or wrought iron in bars with forged ends, for roof work	£15 ditto.
Ditto ditto fixing only	£2 ditto.
Ditto ditto in angle, tee, and channel	£15 ditto.
Ditto ditto fixing only	£2 ditto.
Steel or wrought-iron roofs, per square yard of floor area covered, but not including slating	14s. to 17s.
Steel or wrought iron in bars, with forged ends, for holder work and apparatus generally	£17 per ton.
Ditto fixing only	£2 ditto.
Steel or wrought iron in forgings, small	£18 per ton.
Ditto fixing only	£1 ditto.
Ditto in sheets and plates cold-straightened and punched	£18 ditto.
Ditto rivets and fixing	£2 10s. 10d. ditto.
Ditto in rolled iron girders	£6 to £6 10s. ditto.
Ditto fixing only	15s. ditto.
Ditto riveted girders	£11 to £12 ditto.
Ditto fixing only	10s. to 15s. ditto.
Sheet lead flashing and linings, and labour placing	18s. 6d. per cwt.

It is on these average prices current that the coefficients of cost to be now given are based.

Capacity of the Works.

A Gas-Works capable of producing a maximum of 630,000 cubic feet of gas per day of 24 hours is taken as a basis, and this size of works is adopted as being, though comparatively small, about a fair average, and to give a wider applicability to the figures than they would have had a very large works been assumed.

Using 190 as the multiplier, this is equivalent to an annual production of 120 million cubic feet. Reasonable allowance is also made for future growth in the consumption.

The site of such a works will comprise 2 to 3 statute acres of land. It is assumed that the site is fairly level and such as to admit of its being fully utilized.

This extent of land is capable of containing, without inconvenient crowding, provided the works are laid out with judgment, the whole of the manufacturing, purifying, and storage buildings and apparatus required for the above make of gas per day, and also the buildings and plant for the manufacture of sulphate of ammonia, the recovery of sulphur, and the distillation of tar.

The cost of the apparatus in each case includes erection.

The buildings are assumed to be neat and substantial.

Estimating the production from each mouthpiece or retort (oval or D shaped 21″ × 15″ × 10 feet long) at 6000 feet of gas per day of 24 hours on the average—

The number of mouthpieces required is . . .	105
Add by way of surplus to meet contingencies .	21
Total mouthpieces required . .	126

The retorts are assumed to be in settings of sixes or sevens, and are throughs.

Cost.	Description.	Cost reckoned on the Max. daily (24 hours') Gas production per 1000 Cubic Feet.		Cost per Mouthpiece.
£		£ s. d.		£ s. d.
10,080	*Stage Floor Retort House* with retort stack 20 feet wide, 20 feet space on each side. Retort settings, two dwarf chimneys, generator furnaces, all ironwork (including foul main round the inside of the house), tools, and implements; also covered coal stores to contain six weeks' stock of coal calculated on the maximum days' consumption, with railway communication	16 0 0	..	80 0 0
6,255	*Stage Floor Retort House* and coal stores only, as above	9 18 9	..	49 18 0
3,825	*Retort Stack and two Dwarf Chimneys* built up from basement, with generator furnaces, retort settings, and ironwork complete	6 1 3	..	30 7 0
2,520	*Brickwork of Retort Stack* and two dwarf chimneys, generator furnaces, retorts, and settings, but no ironwork .	4 0 0	..	20 0 0
1,300	*Ironwork* only of stack complete, including hydraulic and foul mains	2 1 3	..	10 7 0
630	*Retorts*, including labour in setting and all fire-clay materials (no ironwork) .	1 0 0	..	5 0 0
630	*Generator Furnaces* and ironwork of same	1 0 0	..	5 0 0
7,000	*Ground Floor Retort House* with retort stack 20 feet wide, 20 feet space on each side, retort settings, two dwarf chimneys, all ironwork (including foul main round the inside of the house), tools, and implements; also covered coal store to contain four weeks' stock of coal calculated on the maximum day's consumption, with railway communication.	11 2 3	..	55 10 0
4,190	*Ground Floor Retort House* and coal stores only, as above	6 13 3	..	33 5 0
2,810	*Retort Stack*, two dwarf chimneys, and retort settings, with iron mountings complete	4 9 0	..	22 5 0
1,606	*Brickwork* of retort stack, two dwarf chimneys, retorts, and settings, but no ironwork	2 11 0	..	12 15 0
1,194	*Ironwork* only of stack, including hydraulic and foul mains	1 18 0	..	9 10 0
630	*Retorts*, including labour in setting and fire-clay materials (no ironwork) . .	1 0 0	..	5 0 0
2,000	*Railway Communication* with an adjoining line of railway. This is an uncertain item, but say as an average	3 2 6	..	16 0 0
460	*Condenser*. This may be of any form, vertical or horizontal (the respective cost will not vary to any great extent), with connections and bye-pass mains and valves complete	0 14 6	..	—

Cost.	Description.	Cost per Square Foot of Purifying Area.	Cost per 1000 Cubic Feet of Gas (maximum) produced per Day.
£		£ s. d.	£ s. d.
535	*Boiler and Exhauster House.* Chimney and setting for two boilers		0 17 0
300	*Steam Boilers* of the Cornish type, two in number, of steel and of ample size to supply steam for exhausters, scrubbers, washer-scrubber, pumps, sulphate apparatus and any other purpose on the works 18′0″ × 5′6″ and all mountings and connections.		0 9 6
330	*Exhauster.* Capacity 40,000 cubic feet per hour driven direct, with its own steam engine, with governor, connections, bye-pass mains and flap-valve complete. Duplicate exhausters are desirable in case of a breakdown		0 10 6
1,325	*Tower Scrubbers,* two in number, 9 feet in diameter and 44 feet high each, with pent-house in addition. Wood filling, liquor and water distributors, washer, at base of first		2 2 0
570	*Washer Scrubber* with steam engine, connections, bye-pass mains and valves. Capacity, 700,000 cubic feet per day		0 18 0
500	*Tar and Ammoniacal Liquor Wells,* two in number, or one divided in two. These are assumed to be underground, built of bricks in Portland cement mortar; capacity equal to four weeks' production of tar and liquor; with separator		0 16 0
80	*Set of three Pumps* with steam engine		0 2 6
3,780	*Purifying House.* Ground floor house with cellar and six purifiers 20 ft. square × 5 ft. deep, and lifting apparatus for purifier lids, wood grids, one centre valve, two 4-way change valves, and all connections 18 in. diameter, complete.	1 11 6	6 0 0
1,260	*House only,* as above	0 10 6	2 0 0
400	*Revivifying Floor* adjoining, for oxide of iron, covered by a roof supported on pillars	0 3 4	0 12 6
4,800	*Two-Storied Purifying House,* including six purifiers 20 feet square and 5 feet deep, placed on upper floor, supported on iron beams and columns; wood grids, one centre valve, and two 4-way change valves, all connections 18 in. diameter; lifting apparatus for purifier lids; revivifying space on ground floor, steam-engine and elevating apparatus for oxide of iron and lime	2 0 0	7 12 6
1,780	*House only,* as above	0 16 6	3 3 0
300	*Oxide Elevating Apparatus* with gearing, belting, and steam engine	0 2 6	0 9 6
2,520	*Purifiers.* Six vessels, 20 ft. square × 5 ft. deep in two sets. The first four with centre valve, and the two last with 4-way valves; with wood grids, lifting tackle for covers, and all connections .	1 1 0	4 0 0

Cost.	Description.	Cost per 1000 Cubic feet Capacity.	Cost per 1000 Cubic Feet of Gas (maximum) produced per Day.
£		£ s. d.	£ s. d.
500	*Station Meter House*, with accommodation for two station meters, and two station governors		0 16 0
425	*Station Meter.* Square connections, with bye-pass valves, and mountings, complete; capacity, 40,000 cubic feet per hour		0 13 6
5,040	*Gasholder Tanks*, two in number, 122 feet diameter, 22½ feet deep = 240,000 cubic feet each, built with bricks laid in Portland cement mortar and puddled . . .	10 10 0	8 0 0
7,040	*Gasholders*, two in number, two-lift, telescopic, 120 feet diameter, 40 feet deep, capacity 430,000 cubic each, together 860,000 cubic feet, equal to 32 hours' (1⅓) days' production; with stand pipes and valves	8 0 0	11 3 6
236	*Station Governors*, 16-inch, two in number, with bye-pass, connections, and valves.		0 7 6
400	*Foundations of Apparatus* throughout the works.		0 12 6
315	*Connections*, valves, and mains, throughout the works 16 in. diameter. Tar pipes, water-pipes, &c	..	0 10 0
65	*Weighbridge* at entrance	..	0 2 0
1,700	*Offices, Workshops, Stores*, testing room and laboratory, and furnishing.		2 14 0
700	*Boundary Wall, Drains*, yard paving, and conveniences .		1 2 0
21,000	*Distributing Plant.* Assuming that the outlay on mains, valves, syphons, and service pipes, amounts to 30 per cent. of the total capital expenditure, which is a fair average, then the cost will be		33 6 8
500	*Sulphate of Ammonia Apparatus*, capacity 5 to 7 tons liquor per 24 hours and appurtenances; including two cast-iron purifiers, 10′ 0″ × 5′ 0″ × 5′ 0″, hydraulic change valve and wood roof on pillars, overhead liquor tank to hold 10 tons, lead-lined acid store tank, and acid supply tank with elevator, pipes, taps, &c.		0 16 0
150	*Buildings* and lead-lined store for ditto		0 12 6
140	*Sulphur Recovery Apparatus*		0 4 6
310	*Tar Distilling Apparatus*		0 10 0
280	*Buildings for ditto*		0 9 0

Description.	Capital Amount.	Per-centage.	Cost per 1000 Cubic Feet of Gas (maximum) produced per Day.
	£		£ s. d.
The Capital of, say, £70,000 would be distributed as under.			
Land, law, parliamentary, and engineering expenses	6,300	9	10 0 0
Floating capital	4,900	7	7 15 6
Buildings (including a stage floor house, the brickwork of the retort stack, the gasholder tanks, tar wells, and foundations of apparatus)	22,400	32	35 11 0
Apparatus and machinery (including the ironwork of retort stack, gasholders, and the apparatus generally)	15,400	22	24 9 0
Distributing plant, mains, service-pipes, &c.	21,000	30	33 6 8
Total	£70,000	100	111 2 2
Dividing the £70,000 Capital under the Heads of the Different Departments.			
Land, law, parliamentary, and engineering expenses	6,300	9	10 0 0
Floating capital	4,900	7	7 15 6
Manufacturing	16,100	23	25 11 0
Purifying (including condenser, scrubbers, washer scrubber, purifiers, &c.)	9,100	13	14 9 0
Storing	12,600	18	20 0 0
Distributing	21,000	30	33 6 8
Total	£70,000	100	111 2 2

MISCELLANEOUS.

BRICKS AND BRICKWORK.

Usual Dimensions of Bricks.

9 inches long; $4\frac{1}{2}$ inches broad; $2\frac{3}{4}$ inches thick.

Weight of 1000 common clay bricks, about $3\frac{1}{4}$ tons.

Weight of 1000 fire-clay bricks, about $3\frac{1}{2}$ tons.

305 common clay bricks weigh about 1 ton.

300 fire-clay bricks weigh about 1 ton.

32 bricks laid flat will pave one square yard.

52 bricks laid on edge will pave one square yard.

Number of bricks in a cubic yard, without mortar, 416.

Number of bricks in a cubic yard, with mortar, 384.

In England, brickwork is generally calculated by the square rod.

A rod of brickwork measures $16\frac{1}{2}$ feet $\times$ $16\frac{1}{2}$ feet $\times$ $1\frac{1}{8}$ feet $=$ 306 cubic feet, or $11\frac{1}{3}$ cubic yards.

A rod of brickwork $=$ 272 superficial feet, $1\frac{1}{2}$ bricks, or $13\frac{1}{2}$ inches thick, which is called the *standard* thickness.

Number of bricks in a rod of brickwork, allowing for waste, 4500.

To reduce brickwork from superficial feet of 9 inches thick to the standard thickness of $13\frac{1}{2}$ inches, deduct one-third.

To reduce brickwork from cubic feet to superficial feet of the standard thickness of $13\frac{1}{2}$ inches, deduct one-ninth.

To reduce brickwork from cubic feet to rods, divide by 306.

To reduce brickwork of more than $1\frac{1}{2}$ bricks thick to superficial feet of the standard thickness of $13\frac{1}{2}$ inches, multiply the area in feet by the number of half bricks in thickness, and divide the product by 3.

To reduce brickwork footings to superficial feet of the standard thickness of $13\frac{1}{2}$ inches, multiply the length by the height of the courses, in feet, and the product by the number of half bricks in the *mean* breadth, and divide by 3. When the number of courses is odd, the number of half bricks in the middle course is the mean. When the number of courses is even, the mean breadth is found by taking half the sum of half bricks in the upper and lower courses.

Bond in Brickwork.

English bond is the strongest, and is a course of stretchers and a course of headers alternately, or one course of headers and one course of stretchers.

Flemish bond is a header and stretcher laid alternately in the same course.

Hoop-iron, when used as bond, should be well tarred and sanded, and bedded in Portland cement.

A rod of brickwork in ordinary buildings requires about—

1 cubic yard of lime.
$2\frac{3}{4}$ cubic yards of sand.

A rod of brickwork in a gasholder tank requires about—

$1\frac{2}{5}$ cubic yards of blue lias lime.
$2\frac{4}{5}$ cubic yards of sharp river sand.

A rod of brickwork requires about—

$1\frac{3}{4}$ cubic yards of Roman or Portland cement.
$1\frac{3}{4}$ cubic yards of sharp river sand.

A cubic yard of quicklime . . .		weighs	about	1460	lbs.
,, ,,	blue lias quicklime	,,	,,	1470	,,
,, ,,	Portland cement .	,,	,,	2416	,,
,, ,,	Roman cement .	,,	,,	1700	,,
,, ,,	dry sand . . .	,,	,,	2430	,,

The above materials, when made into mortar, lose about one-third of their bulk.

Fire-Clay.

The value of fire-clay consists chiefly in the proportion of the alumina to the fusible matter (viz., oxide of iron, and the alkalies of magnesia, potassa and soda, &c.) and to the silica; these being the principal ingredients of which it is composed. The larger the proportion of alumina to the fusible matter, the more refractory the clay. Of two clays containing alumina and fusible matter in the same proportions, that which contains the least silica is the more refractory.

The celebrated clays of Stourbridge, Newcastle-on-Tyne, different parts of Yorkshire, Scotland, and a few other places, are valuable in the manufacture of bricks, tiles, and retorts used in furnaces for the distillation of coal.

The table on next page will be found useful in this connection.

TABLE

Exhibiting the usual Constituents of the Chief English and Foreign Fire-Clays.

Locality.	Silica.	Alumina.	Peroxide of Iron.	Peroxide of Manganese.	Phosphate of Iron.	Lime.	Magnesia.	Potassa.	Soda.	Titanic Acid.	Water, Organic Matter, &c.	Total.
Stourbridge	65·37	26·48	5·68	..	..	·28	·33	1·26	·30	·30	..	100
Plympton, Devonshire .	74·02	21·37	1·94	..	..	·40	·36	1·82	·09	..	..	100
Newcastle-on-Tyne . .	64·63	29·78	3·23	..	..	·42	·41	1·09	·24	·20	..	100
Burton-on-Trent . .	58·08	36·09	3·06	..	..	·55	·14	·20	1·88	..	..	100
Wortley, near Leeds .	65·25	29·71	3·07	..	..	·40	·61	·43	1·12	.41	..	100
Derbyshire	48·06	36·89	2·26	..	..	..	..	1·88	..	..	10·89	100
Hedgerley, Bucks* . .	84·65	8·85	4·25	..	..	1·90	·35	..	..	..	..	100
Poole, Dorsetshire . .	59·35	34·32	2·35	..	..	·43	·22	3·33	..	..	..	100
Monmouthshire . . .	75·30	16·80	1·00	..	..	·90	..	..	..	..	6·00	100
Pembrokeshire . . .	88·43	6·90	1·50	..	..	3·17	..	..	..	..	..	100
Dinas, Glamorganshire	97·62	1·40	·49	..	..	·29	..	·10	·10	..	..	100
Kilmarnock, Scotland .	58·92	35·65	2·49	..	..	·39	·35	1·14	1·06	..	..	100
Perceton, Scotland . .	62·50	35·00	·90	·20	·50	·60	·30	..	..	..	..	100
Govan, Scotland . . .	60·20	37·70	1·10	..	..	1·00	..	..	..	..	..	100
France	66·10	19·80	..	..	..	..	..	..	..	..	14·10	100
Hesse	47·50	34·37	1·24	..	..	..	1·00	..	..	..	15·89	100
Bavaria	45·79	28·10	6·55	..	..	..	..	..	..	..	19·56	100

Authorities—Berthier, Cowper, Salvett, Muspratt, Richardson, Kitt, and Grover.

* Windsor bricks.

TABLES,

Showing the Number of Bricks in Walls of different Areas, from ½ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

TABLE I.—*From 1 to 50 Superficial Feet.*

Area of Wall. Sup. Feet.	½ Brick on Bed.	1 Brick Thick.	1½ Bricks Thick.	2 Bricks Thick.	2½ Bricks Thick.	3 Bricks Thick.	3½ Bricks Thick.	4 Bricks Thick.
1	6	11	17	22	28	33	39	44
2	11	22	33	44	55	66	77	88
3	17	33	50	66	83	99	116	132
4	22	44	66	88	110	132	154	176
5	28	55	83	110	138	165	193	221
6	33	66	99	132	165	199	232	265
7	39	77	116	154	193	232	270	309
8	44	88	132	176	221	265	309	353
9	50	99	149	199	248	298	347	397
10	55	110	165	221	276	331	386	441
11	61	121	182	243	303	364	425	485
12	66	132	199	265	331	397	463	529
13	72	143	215	287	358	430	502	574
14	77	154	232	309	386	463	540	618
15	83	165	248	331	414	496	579	662
16	88	176	265	353	441	529	618	706
17	94	187	281	375	469	563	656	750
18	99	199	298	397	496	596	695	794
19	105	210	314	419	524	629	733	838
20	110	221	331	441	551	662	772	882
21	116	232	347	463	579	695	811	926
22	121	243	364	485	607	728	849	971
23	127	254	381	507	634	761	888	1015
24	132	265	397	529	662	794	926	1059
25	138	276	414	551	689	827	965	1103
26	143	287	430	574	717	860	1004	1147
27	149	298	447	596	744	893	1042	1191
28	154	309	463	618	772	926	1081	1235
29	160	320	480	640	800	960	1119	1279
30	165	331	496	662	827	993	1158	1324
31	171	342	513	684	855	1026	1197	1368
32	176	353	529	706	882	1059	1235	1412
33	182	364	546	728	910	1092	1274	1456
34	188	375	563	750	938	1125	1313	1500
35	193	386	579	772	965	1158	1351	1544
36	199	397	596	794	993	1191	1390	1588
37	204	408	612	816	1020	1224	1428	1632
38	210	419	629	838	1048	1257	1467	1676
39	215	430	645	860	1075	1290	1506	1721
40	221	441	662	882	1103	1324	1544	1765
41	226	452	678	904	1131	1357	1583	1809
42	232	463	695	926	1158	1390	1621	1853
43	237	474	711	949	1186	1423	1660	1897
44	243	485	728	971	1213	1456	1699	1941
45	248	496	744	993	1241	1489	1737	1985
46	254	507	761	1015	1268	1522	1776	2029
47	259	518	778	1037	1296	1555	1814	2074
48	265	529	794	1059	1324	1588	1853	2118
49	270	540	811	1081	1351	1621	1892	2162
50	276	551	827	1103	1379	1654	1930	2206

Showing the Number of Bricks in Walls of different Areas, from ½ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

Table II.—51 to 100 *Superficial Feet.*

Area of Wall. Sup. Feet.	½ Brick on Bed.	1 Brick thick.	1½ Bricks thick.	2 Bricks thick.	2½ Bricks thick.	3 Bricks thick.	3½ Bricks thick.	4 Bricks thick.
51	281	563	844	1125	1406	1688	1969	2250
52	287	574	860	1147	1434	1721	2007	2294
53	292	584	877	1169	1461	1754	2046	2338
54	298	596	893	1191	1489	1787	2085	2382
55	303	607	910	1213	1517	1820	2123	2426
56	309	618	926	1235	1544	1853	2162	2471
57	314	629	943	1257	1572	1886	2200	2515
58	320	640	960	1279	1599	1919	2239	2559
59	325	651	976	1301	1627	1952	2278	2603
60	331	662	993	1323	1654	1985	2316	2647
61	336	673	1009	1346	1682	2018	2355	2691
62	342	684	1026	1368	1710	2051	2393	2735
63	347	695	1042	1390	1737	2085	2432	2779
64	353	706	1059	1412	1765	2118	2471	2824
65	358	717	1075	1434	1792	2151	2509	2868
66	364	728	1092	1456	1820	2184	2548	2912
67	369	739	1108	1478	1847	2217	2586	2956
68	375	750	1125	1500	1875	2250	2625	3000
69	381	761	1142	1522	1903	2283	2664	3044
70	386	772	1158	1544	1939	2316	2702	3088
71	392	783	1175	1566	1958	2349	2741	3132
72	397	794	1191	1588	1985	2382	2779	3177
73	403	805	1208	1610	2013	2415	2818	3221
74	408	816	1224	1632	2040	2449	2857	3265
75	414	827	1241	1654	2068	2482	2895	3309
76	419	838	1257	1676	2096	2515	2934	3353
77	425	849	1274	1699	2123	2548	2972	3397
78	430	860	1290	1721	2151	2581	3011	3441
79	436	871	1307	1743	2178	2614	3050	3485
80	441	882	1324	1765	2206	2647	3088	3529
81	447	893	1340	1787	2233	2680	3127	3574
82	452	904	1357	1809	2261	2713	3165	3618
83	458	915	1373	1831	2289	2746	3204	3662
84	463	926	1390	1853	2316	2779	3243	3706
85	469	938	1406	1875	2344	2813	3281	3750
86	474	949	1423	1897	2371	2846	3320	3794
87	480	960	1439	1919	2399	2879	3358	3838
88	485	970	1456	1941	2426	2912	3397	3882
89	491	982	1472	1963	2454	2945	3436	3926
90	496	993	1489	1985	2482	2978	3474	3971
91	502	1004	1506	2007	2509	3011	3513	4015
92	507	1015	1522	2029	2537	3044	3551	4059
93	513	1026	1539	2051	2564	3077	3590	4103
94	518	1037	1555	2074	2592	3110	3629	4147
95	524	1048	1572	2096	2619	3143	3667	4191
96	529	1059	1588	2118	2647	3176	3706	4235
97	535	1070	1605	2140	2675	3210	3744	4279
98	540	1081	1621	2162	2702	3243	3783	4324
99	546	1092	1638	2184	2730	3276	3822	4368
100	551	1103	1654	2206	2757	3309	3860	4412

Showing the Number of Bricks in walls of different Areas, from ½ Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

TABLE III.—*From 110 to 600 Superficial Feet.*

Area of Wall. Sup. Feet.	½ Brick on Bed.	1 Brick thick.	1½ Bricks thick.	2 Bricks thick.	2½ Bricks thick.	3 Bricks thick.	3½ Bricks thick.	4 Bricks thick.
110	607	1213	1820	2426	3033	3640	4246	4853
120	662	1324	1985	2647	3309	3971	4632	5294
130	717	1434	2151	2868	3585	4301	5018	5735
140	772	1544	2316	3088	3860	4632	5404	6176
150	827	1654	2482	3309	4136	4963	5790	6618
160	882	1765	2647	3529	4412	5294	6176	7059
170	938	1875	2813	3750	4688	5625	6563	7500
180	993	1985	2978	3971	4963	5956	6949	7941
190	1048	2096	3143	4191	5239	6287	7335	8382
200	1103	2206	3309	4412	5515	6618	7721	8824
210	1158	2316	3474	4632	5790	6949	8107	9265
220	1213	2426	3640	4853	6066	7279	8493	9706
230	1268	2537	3805	5074	6342	7610	8879	10,147
240	1324	2647	3971	5294	6618	7941	9265	10,588
250	1379	2757	4136	5515	6893	8272	9651	11,029
260	1434	2868	4301	5735	7169	8603	10,037	11,471
270	1489	2978	4467	5956	7445	8934	10,423	11,912
280	1544	3088	4632	6176	7721	9265	10,809	12,353
290	1599	3199	4798	6397	7996	9596	11,195	12,794
300	1654	3309	4963	6618	8272	9926	11,581	13,235
310	1710	3419	5129	6838	8548	10,257	11,967	13,676
320	1765	3529	5294	7059	8824	10,588	12,353	14,118
330	1820	3640	5460	7279	9099	10,919	12,789	14,559
340	1875	3750	5625	7500	9375	11,250	13,125	15,000
350	1930	3860	5790	7721	9651	11,581	13,511	15,441
360	1985	3971	5956	7941	9926	11,912	13,897	15,882
370	2040	4081	6121	8162	10,202	12,243	14,283	16,324
380	2096	4191	6287	8382	10,478	12,574	14,669	16,765
390	2151	4301	6452	8603	10,754	12,904	15,055	17,206
400	2206	4412	6618	8824	11,029	13,235	15,441	17,647
410	2261	4522	6783	9044	11,305	13,566	15,827	18,088
420	2316	4632	6949	9265	11,581	13,897	16,213	18,529
430	2371	4743	7114	9485	11,857	14,228	16,599	18,971
440	2426	4853	7279	9706	12,132	14,559	16,985	19,412
450	2482	4963	7445	9926	12,408	14,890	17,371	19,853
460	2537	5074	7610	10,147	12,684	15,221	17,757	20,294
470	2592	5184	7776	10,368	12,960	15,551	18,143	20,735
480	2647	5294	7941	10,588	13,235	15,882	18,529	21,176
490	2702	5404	8107	10,809	13,511	16,213	18,915	21,618
500	2757	5515	8272	11,029	13,787	16,544	19,301	22,059
510	2813	5625	8438	11,250	14,063	16,875	19,688	22,500
520	2868	5735	8603	11,471	14,338	17,206	20,074	22,941
530	2923	5846	8768	11,691	14.064	17,537	20,460	23,382
540	2978	5956	8934	11,912	14,890	17,868	20,846	23,824
550	3033	6066	9099	12,132	15,165	18,199	21,232	24,265
560	3088	6176	9265	12,353	15,441	18,529	21,618	24,706
570	3143	6287	9430	12,574	15,717	18,860	22,004	25,147
580	3199	6397	9596	12,794	15,993	19,191	22,390	25,588
590	3254	6507	9761	13,015	16,268	19,522	22,776	26,029
600	3309	6618	9926	13,235	16,544	19,853	23,162	26,471

Showing the Number of Bricks in Walls of different Areas, from ½ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

TABLE IV.—*From* 610 *to* 2000 *Superficial Feet.*

Area of Wall Sup. Feet.	½ Brick on Bed.	1 Brick thick.	1½ Bricks thick.	2 Bricks thick.	2½ Bricks thick.	3 Bricks thick.	3½ Bricks thick.	4 Bricks thick.
610	3364	6728	10,092	13,456	16,820	20,184	23,548	26,912
620	3419	6838	10,257	13,676	17,096	20,515	23,934	27,353
630	3474	6949	10,423	13,897	17,371	20,846	24,320	27,794
640	3529	7059	10,588	14,118	17,647	21,176	24,706	28,235
650	3585	7169	10,754	14,338	17,923	21,507	25,092	28,676
660	3640	7279	10,919	14,559	18,199	21,838	25,478	29,118
670	3695	7390	11,085	14,779	18,474	22,169	25,864	29,559
680	3750	7500	11,250	15,000	18,750	22,500	26,250	30,000
690	3805	7610	11,415	15,221	19,026	22,831	26,636	30,441
700	3860	7721	11,581	15,441	19,301	23,162	27,022	30,882
710	3915	7831	11,746	15,662	19,577	23,493	27,408	31,324
720	3971	7941	11,912	15,882	19,853	23,824	27,794	31,765
730	4026	8051	12,077	16,103	20,129	24,154	28,180	32,206
740	4081	8162	12,243	16,324	20,404	24,485	28,566	32,647
750	4136	8272	12,408	16,544	20,680	24,816	28,952	33,088
760	4191	8382	12,574	16,765	20,956	25,147	29,338	33,529
770	4246	8493	12,739	16,985	21,232	25,478	29,724	33,971
780	4301	8603	12,904	17,206	21,507	25,809	30,110	34,412
790	4357	8713	13,070	17,426	21,783	26,140	30,496	34,853
800	4412	8824	13,235	17,647	22,059	26,471	30,882	35,294
810	4467	8934	13,401	17,868	22,335	26,801	31,268	35,735
820	4522	9044	13,566	18,088	22,610	27,132	31,654	36,176
830	4577	9154	13,732	18,309	22,886	27,463	32,040	36,618
840	4632	9265	13,897	18,529	23,162	27,794	32,426	37,059
850	4688	9375	14,063	18,750	23,438	28,125	32,813	37,500
860	4743	9485	14,228	18,971	23,713	28,456	33,199	37,941
870	4798	9596	14,393	19,191	23,989	28,787	33,585	38,382
880	4853	9706	14,559	19,412	24,265	29,118	33,971	38,824
890	4908	9816	14,724	19,632	24,540	29,449	34,357	39,265
900	4963	9926	14.890	19,853	24,816	29,779	34,743	39,706
910	5018	10,037	15,055	20,074	25,092	30,110	35,129	40,147
920	5074	10,147	15,221	20,294	25,368	30,441	35,515	40,588
930	5129	10,257	15,386	20,515	25,643	30,772	35,901	41,029
940	5184	10,368	15,551	20,735	25,919	31,103	36,287	41,471
950	5239	10,478	15,717	20,956	26,195	31,434	37,673	41,912
960	5294	10,588	15,882	21,176	26,471	31,765	37,059	42,353
970	5349	10,699	16,048	21,397	26,746	32,096	37,445	42,794
980	5404	10,809	16,213	21,618	27,022	32,426	37,831	43,235
990	5460	10,919	16,379	21,838	27,298	32,757	38,217	43,676
1000	5515	11,029	16,544	22,059	27,574	33,088	38,603	44,118
1100	6066	12,132	18,199	24,265	30,331	36,397	42,463	48,529
1200	6618	13,235	19,853	26,471	33,088	39,706	46,324	52,941
1300	7169	14,338	21,507	28,676	35,846	43,015	50,184	57,353
1400	7721	15,441	23,162	30,882	38,603	46,324	54,044	61,765
1500	8272	16,544	24,816	33,088	41,360	49,632	57,904	66,176
1600	8824	17,647	26,471	35.294	44,118	52,941	61.765	70,588
1700	9375	18,750	28,125	37,500	46,825	56,250	65,625	75,000
1800	9926	19,853	29,779	39,706	49,632	59,559	69,485	79,412
1900	10,478	20,956	31,434	41,912	52,390	62,868	73,346	83,824
2000	11,029	22,059	33,088	44,118	55,147	66,176	77,206	88,235

Showing the Number of Bricks in Walls of different Areas from ½ a Brick up to 4 Bricks thick. Reckoned at 4500 Bricks to the Rod (272 feet super.), allowing for Waste.

Table V.—*From 2100 to 250,000 Superficial Feet.*

Area of Wall. Sup. Feet.	½ Brick on Bed.	1 Brick thick.	1½ Bricks thick.	2 Bricks thick.	2½ Bricks thick.	3 Bricks thick.	3½ Bricks thick.	4 Bricks thick.
2100	11,581	23,162	34,743	46,324	57,904	69,485	81,066	92,647
2200	12,132	24,265	36,397	48,529	60,662	72,794	84,926	97,059
2300	12,684	25,368	38,051	50,735	63,419	76,103	88,787	101,471
2400	13,235	26,471	39,706	52,941	66,176	79,412	92,647	105,882
2500	13,787	27,574	41,360	55,147	68,934	82,721	96,507	110,294
2600	14,338	28,676	43,015	57,353	71,691	86,029	100,368	114,706
2700	14,890	29,779	44,669	59,559	74,449	89,338	104,228	119,118
2800	15,441	30,882	46,324	61,765	77,206	92,647	108,088	123,529
2900	15,993	31,985	47,278	63,971	79,963	95,956	111,949	127,941
3000	16,544	33,088	49,632	66,176	82,721	99,265	115,809	132,353
3100	17,096	34,191	51,287	68,382	85,478	102,574	119,669	136,765
3200	17,647	35,294	52,941	70,588	88,235	105,882	123,529	141,176
3300	18,199	36,397	54,596	72,794	90,993	109,191	127,390	145,588
3400	18,750	37,500	56,250	75,000	93,750	112,500	131,250	150,000
3500	19,301	38,603	57,904	77,206	96,507	115,809	135,110	154,412
3600	19,853	39,706	59,559	79,412	99,265	119,118	138,971	158,824
3700	20,404	40,809	61,213	81,618	102,022	122,426	142,831	163,235
3800	20,956	41,912	62,868	83,824	104,779	125,735	146,691	167,647
3900	21,507	43,015	64,522	86,029	107,537	129,044	150,551	172,059
4000	22,059	44,118	66,176	88,235	110,294	132,353	154,412	176,471
4100	22,610	45,221	67,831	90,441	113,051	135,662	158,272	180,882
4200	23,162	46,324	69,485	92,647	115,809	138,971	162,132	185,294
4300	23,713	47,426	71,140	94,853	118,566	142,279	165,993	189,706
4400	24,265	48,529	72,794	97,059	121,324	145,588	169,853	194,118
4500	24,816	49,632	74,449	99,265	124,081	148,897	173,713	198,529
4600	24,368	50,735	76,103	101,471	126,838	152,206	177,574	202,941
4700	25,919	51,838	77,757	103,676	129,596	155,515	181,434	207,353
4800	26,471	52,941	79,412	105,882	132,353	158,824	185,294	211,765
4900	27,022	54,044	81,066	108,088	135,110	162,132	189,154	216,176
5000	27,574	55,147	82,721	110,294	137,868	165,441	193,015	220,588
10,000	55,147	110,294	165,441	220,588	275,735	330,882	386,029	441.176
15,000	82,721	165,441	248,162	330,882	413,603	496,324	579,044	661,765
20,000	110,294	220,588	330,882	441,176	551,471	661,765	772,059	882,353
25,000	137,868	275,735	413,603	551,471	689,338	827,206	965,074	1,102,941
30,000	165,441	330,882	496,324	661,765	827,206	992,647	1,158,088	1,323,529
35,000	193,015	386,029	579,044	772,059	965,074	1,158,088	1,351,103	1,544,118
40,000	220,588	441,176	661,765	882,353	1,102,941	1,323,529	1,544,118	1,764,706
45,000	248,162	496,324	744,485	992,647	1,240,809	1,488,971	1,737,132	1,985,294
50,000	275,735	551,471	827,206	1,102,941	1,378,676	1,654,412	1,930,147	2,205,882
55,000	303,309	606,618	909,926	1,213,235	1,516,544	1,819,753	2,123,162	2,426,471
60,000	330,882	661,765	992,647	1,323,529	1,654,412	1,985,294	2,316,176	2,647,059
65,000	358,456	716,912	1,075,368	1,433,824	1,792,279	2,150,735	2,509,191	2,867,647
70,000	386,029	772,059	1,158,088	1,544,118	1,930,147	2,316,176	2,702,206	3,088,235
75,000	413,603	827,206	1,240,809	1,654,412	2,068,015	2,481,618	2,895,221	3,308,824
80,000	441,176	882,353	1,323,529	1,764,706	2,205,882	2,647,059	3,088,235	3,529,412
85,000	468,750	937,500	1,406,250	1,875,000	2,343,750	2,812,500	3,281,250	3,750,000
90,000	496,324	992,647	1,488,971	1,985,294	2,481,618	2,977,941	3,474,265	3,970,588
95,000	523,897	1,047,794	1,571,791	2,095,588	2,619,485	3,143,382	3,667,279	4,191,176
100,000	551,471	1,102,941	1,654,412	2,205,882	2,757,353	3,308,824	3,860,294	4,411,765
150,100	827,206	1,654,412	2,481,618	3,308,824	4,136,029	4,963,235	5,790,441	6,617,647
200,000	1,102,941	2,205,882	3,308,824	4,411,765	5,514,706	6,617,647	7,720,588	8,823,529
250,000	1,378,676	2,757,353	4,136,029	5,514,706	6,893,382	8,272,059	9,650,735	11,029,412

MORTAR AND CONCRETE.

Mortar.

	By Measure.
Lime	1 part.
Sharp river sand	3 parts.

or,

Lime	1 part.
Sand	2 parts.
Blacksmith's ashes or clinker, ground	1 part.

Coarse Mortar.

Lime	1 part.
Coarse sand	4 parts.

Hydraulic Lime Mortar.

Best blue lias lime	1 part.
Clean sharp river sand	$2\frac{1}{2}$ parts.

or,

Best blue lias lime	1 part.
Burnt clay	2 parts.

or,

Best blue lias lime	1 part.
Puzzolana	1 part.
Clean sharp sand	6 parts.

Cement Mortar.

Cement, Portland	1 part.
Clean sharp sand	3 parts.

The lime should be fresh burnt, and not more than sufficient of the mortar for a day's work prepared at once. The cement mortar should only be made as it is being used.

Concrete.

	By Measure.
Blue lias lime concrete (for foundations)—	
Gravel, shingle, broken stone, bricks, or old retorts, $1\frac{1}{2}$ to 2 inches cube	6 parts.
Clean sharp sand	2 parts.
Blue lias or other hydraulic lime	1 part.
Portland cement concrete (for tank walls)—	
Gravel, shingle, broken stone, bricks, or old retorts, $1\frac{1}{2}$ inches cube	7 parts.
Clean sharp sand	2 parts.
Portland cement	1 part.

Mastic Cement for Buildings.

1 part red lead.	1 part red lead.
5 parts ground lime.	5 parts whiting.
5 parts sharp sand	10 parts sharp sand.
Mix with boiled linseed oil.	Mix with boiled linseed oil.

Clean sharp sand (not having its particles rounded by attrition) should always be used in the composition of mortar when it can be procured; but, otherwise, clean well-burnt ashes may be substituted.

In preparing ordinary mortar it is desirable to mix a small proportion of smithy ashes with the lime and sand. On this subject Mr. Graham Smith remarks ("Engineering Papers," p. 20): "The importance of the admixture of ashes with mortar to be atmospherically dried will be shown by the following results:—The bricklayers' mortar, with common bricks, after a lapse of 84 days, broke with 570 lbs.; when sand was substituted in place of ashes—that is, when the proportions were 1 slaked lime, 2 sand, and no ashes—it only required 257 lbs. to tear asunder the bricks. These are the averages of three experiments. This is no doubt attributable to the ashes being porous; they thus allow greater facilities for the absorption of carbonic acid from the atmosphere."

The more sand that can be incorporated with the lime, the better the mortar, provided the necessary degree of plasticity is preserved.

A load of mortar is equal to one cubic yard.

A hod of mortar measures 9 in. × 9 in. × 14 in.

Two hods of mortar are nearly equal to a bushel.

The mortar in a rod of brickwork (4500 bricks) is taken at $1\frac{1}{2}$ cwt. of chalk lime and 2 loads of sand, or 1 cwt. of stone lime and $2\frac{1}{2}$ loads of sand.

Handy Multiplier for Wrought-Iron.

If the area in square inches of the cross section of any specimen of wrought iron be multiplied by 3·34, the product will be the weight in pounds of a lineal foot of such specimen.

FLAT BAR IRON.—*Weight in lbs. of a Lineal Foot.*

Breadth in Inches.	Thickness in Parts of an Inch.								
	1-4th.	5-16ths.	3-8ths.	7-16ths.	1-half.	5-8ths.	3-4ths.	7-8ths.	1
1	·835	1·044	1·253	1·461	1·670	2·088	2·506	2·923	3·340
$1\frac{1}{8}$	·939	1·174	1·409	1·644	1·878	2·348	2·818	3·287	3·756
$1\frac{1}{4}$	1·044	1·305	1·566	1·826	2·088	2·609	3·132	3·653	4·176
$1\frac{3}{8}$	1·148	1·435	1·722	2·009	2·296	2·870	3·444	4·018	4·592
$1\frac{1}{2}$	1·252	1·566	1·879	2·192	2·504	3·131	3·758	4·384	5·008
$1\frac{5}{8}$	1·358	1·696	2·035	2·374	2·716	3·392	4·070	4·749	5·432
$1\frac{3}{4}$	1·462	1·827	2·192	2·557	2·924	3·653	4·384	5·114	5·848
$1\frac{7}{8}$	1·566	1·957	2·348	2·740	3·132	3·914	4·696	5·479	6·264
2	1·671	2·088	2·505	2·922	3·342	4·175	6·010	5·845	6·684
$2\frac{1}{8}$	1·775	2·218	2·662	3·105	3·550	4·435	5·324	6·210	7·100
$2\frac{1}{4}$	1·880	2·348	2·818	3·288	3·760	4·696	5·636	6·575	7·520
$2\frac{3}{8}$	1·984	2·479	2·975	3·470	3·968	4·957	5·950	6·941	7·936
$2\frac{1}{2}$	2·088	2·609	3·131	3·653	4·176	5·218	6·262	7·306	8·352
$2\frac{5}{8}$	2·193	2·740	3·288	3·836	4·386	5·479	6·576	7·671	8·772
$2\frac{3}{4}$	2·297	2·870	3·444	4·018	4·594	5·740	6·888	8·036	9·188
$2\frac{7}{8}$	2·402	3·001	3·601	4·201	4·804	6·001	7·202	8·402	9·608
3	2·506	3·131	3·758	4·384	5·012	6·262	7·516	8·767	10·024
$3\frac{1}{4}$	2·715	3·392	4·071	4·749	5·430	6·784	8·142	9·498	10·860
$3\frac{1}{2}$	2·923	3·653	4·384	5·114	5·846	7·306	8·768	10·228	11·692
$3\frac{3}{4}$	3·132	3·914	4·697	5·479	6·264	7·828	9·394	10·959	12·528
4	3·341	4·175	5·010	5·845	6·682	8·350	10·020	11·690	13·364
$4\frac{1}{4}$	3·549	4·436	5·323	6·210	7·098	8·871	10·646	12·421	14·196
$4\frac{1}{2}$	3·758	4·697	5·636	6·575	7·516	9·393	11·272	13·151	15·032
$4\frac{3}{4}$	3·966	4·958	5·949	6·941	7·932	9·915	11·898	13·881	15·864
5	4·175	5·219	6·263	7·306	8·350	10·437	12·526	14·612	16·700
$5\frac{1}{4}$	4·384	5·479	6·576	7·671	8·768	10·958	13·152	15·343	17·536
$5\frac{1}{2}$	4·593	5·741	6·889	8·037	9·186	11·480	13·778	16·073	18·372
$5\frac{3}{4}$	4·801	6·001	7·202	8·402	9·602	12·002	14·404	16·804	19·204
6	5·010	6·262	7·515	8·767	10·020	12·524	15·030	17·535	20·042

ROUND BAR IRON.—*Weight in lbs. of a Lineal Foot.*

Diameter in Inches.	Weight in lbs.	Diameter in Inches.	Weight in lbs.	Diameter in Inches.	Weight in lbs.	Diameter in Inches.	Weight in lbs.
$\frac{1}{8}$	·040	$1\frac{5}{8}$	6·870	$3\frac{1}{8}$	25·400	$4\frac{5}{8}$	55·640
$\frac{1}{4}$	·163	$1\frac{3}{4}$	7·970	$3\frac{1}{4}$	27·475	$4\frac{3}{4}$	58·688
$\frac{3}{8}$	·363	$1\frac{7}{8}$	9·150	$3\frac{3}{8}$	29·625	$4\frac{7}{8}$	61·820
$\frac{1}{2}$	·650	2	10·406	$3\frac{1}{2}$	31·870	5	65·040
$\frac{5}{8}$	1·006	$2\frac{1}{8}$	11·750	$3\frac{5}{8}$	34·175	$5\frac{1}{8}$	68·330
$\frac{3}{4}$	1·456	$2\frac{1}{4}$	13·106	$3\frac{3}{4}$	36·575	$5\frac{1}{4}$	71·700
$\frac{7}{8}$	1·990	$2\frac{3}{8}$	14·670	$3\frac{7}{8}$	39·056	$5\frac{3}{8}$	75·150
1	2·590	$2\frac{1}{2}$	16·256	4	41·620	$5\frac{1}{2}$	78·700
$1\frac{1}{8}$	3·300	$2\frac{5}{8}$	17·925	$4\frac{1}{8}$	44·260	$5\frac{5}{8}$	82·300
$1\frac{1}{4}$	4·070	$2\frac{3}{4}$	19·600	$4\frac{1}{4}$	46·990	$5\frac{3}{4}$	86·006
$1\frac{3}{8}$	4·920	$2\frac{7}{8}$	21·500	$4\frac{3}{8}$	49·790	$5\frac{7}{8}$	89·800
$1\frac{1}{2}$	5·860	3	23·406	$4\frac{1}{2}$	52·675	6	93·650

SQUARE BAR IRON.

Weight in lbs. of a Lineal Foot.

Side in Inches.	Weight in lbs.	Side in Inches.	Weight in lbs.	Side in Inches.	Weight in lbs.	Side in Inches.	Weight in lbs.
1/8	·052	1 5/8	8·82	3 1/8	32·72	4 5/8	71·60
1/4	·208	1 3/4	10·23	3 1/4	35·28	4 3/4	75·36
3/8	·469	1 7/8	11·74	3 3/8	38·16	4 7/8	79·54
1/2	·832	2	13·36	3 1/2	40·92	5	83·44
5/8	1·304	2 1/8	15·08	3 5/8	44·01	5 1/8	87·90
3/4	1·876	2 1/4	16·91	3 3/4	46·96	5 1/4	92·40
7/8	2·557	2 3/8	18·84	3 7/8	50·38	5 3/8	96·67
1	3·340	2 1/2	20·86	4	53·44	5 1/2	101·04
1 1/8	4·227	2 5/8	23·10	4 1/8	56·97	5 5/8	105·87
1 1/4	5·216	2 3/4	25·25	4 1/4	60·32	5 3/4	110·80
1 3/8	6·314	2 7/8	27·70	4 3/8	64·08	5 7/8	115·48
1 1/2	7·504	3	30·02	4 1/2	67·64	6	120·08

SHEET IRON AND STEEL.

Weight of a Superficial Foot in Pounds and Fractions, with Corresponding Number and Thickness of Birmingham Wire Gauge.

No. of Birmingham Wire Gauge.	Thickness in Parts of an Inch. Board of Trade Standard.	Weight per Square Foot in lbs. Iron.	Weight per Square Foot in lbs. Steel.	No. of Birmingham Wire Gauge.	Thickness in Parts of an Inch. Board of Trade Standard.	Weight per Square Foot in lbs. Iron.	Weight per Square Foot in lbs. Steel.
1	·300	12·00	12·240	19	·041	1·64	1·673
2	·284	11·36	11·587	20	·035	1·40	1·428
3	·260	10·40	10·608	21	·032	1·28	1·306
4	·238	9·52	9·710	22	·028	1·12	1·142
5	·220	8·80	8·976	23	·025	1·00	1·020
6	·203	8·12	8·282	24	·022	0·88	0·898
7	·180	7·20	7·344	25	·020	0·80	0·816
8	·165	6·60	6·732	26	·018	0·72	0·734
9	·148	5·92	6·038	27	·016	0·64	0·653
10	·135	5·40	5·508	28	·014	0·56	0·571
11	·120	4·80	4·896	29	·013	0·52	0·530
12	·109	4·36	4·447	30	·012	0·48	0·490
13	·095	3·80	3·876	31	·010	0·40	0·408
14	·083	3·32	3·386	32	·009	0·36	0·367
15	·072	2·88	2·938	33	·008	0·32	0·326
16	·065	2·60	2·652	34	·007	0·28	0·286
17	·058	2·32	2·366	35	·005	0·20	0·240
18	·050	2·00	2·040	36	·004	0·16	0·163

At a Special Meeting of the Iron Trade, held on February 28, 1896, it was resolved that the Standard of Measurement for Iron of all descriptions shall in future be the Birmingham Gauge. It was

further decided that the annexed table of decimal equivalents be adopted as corresponding with the number on the Gauge.

	No. B. G.	Fractions of an Inch.	Decimal Equival'nts of an Inch.	No. B. G.	Fractions of an Inch.	Decimal Equival'nts of an Inch.	
	000	1/2	·5	14	..	·0785	
	00	..	·4452	15	..	·0699	
	0	..	·3964	16	1/16	·0625	
	1	..	·3532	17	..	·0556	
	2	..	·3147	18	..	·0495	
Plates	3	..	·2804	19	..	·044	
	4	1/4	·25	20	..	·0392	
	5	..	·2225	21	..	·0349	
	6	..	·1981	22	1/32	·03125	Sheets.
	7	..	·1764	23	..	·0278	
	8	..	·157	24	..	·0247	
	9	..	·1398	25	..	·022	
Sheets	10	1/8	·125	26	..	·0196	
	11	..	·1113	27	..	·0174	
	12	..	·0991	28	1/64	·015625	
	13	..	·0882	29	..	·0139	
				30	..	·0123	

STEEL.

Weight of One Foot of Round Steel.

Diameter in Inches.	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
Weight per Foot in lbs.	·167	·373	·669	1·04	1·05	2·05	2·67	3·38	4·18	5·06	6·02	7·07	8·2	9·41	11·71

WEIGHT IN POUNDS OF A SUPERFICIAL FOOT OF IRON, COPPER, AND BRASS.

Thickness by the Birmingham Wire Gauge.	Iron. lbs.	Copper. lbs.	Brass. lbs.	Thickness by the Birmingham Wire Gauge.	Iron. lbs.	Copper. lbs.	Brass. lbs.
1	12·50	14·50	13·75	16	2·50	2·90	2·75
2	12·00	13·90	13·20	17	2·18	2·52	2·40
3	11·00	12·75	12·10	18	1·86	2·15	2·04
4	10·00	11·60	11·00	19	1·70	1·97	1·87
5	8·74	10·10	9·61	20	1·54	1·78	1·69
6	8·12	9·40	8·93	21	1·40	1·62	1·54
7	7·50	8·70	8·25	22	1·25	1·46	1·37
8	6·86	7·90	7·54	23	1·12	1·30	1·23
9	6·24	7·20	6·86	24	1·00	1·16	1·10
10	5·62	6·50	6·18	25	·90	1·04	·99
11	5·00	5·80	5·50	26	·80	·92	·88
12	4·38	5·08	4·81	27	·72	·83	·79
13	3·75	4·34	4·12	28	·64	·74	·70
14	3·12	3·60	3·43	29	·56	·64	·61
15	2·82	3·27	3·10	30	·50	·58	·55

WEIGHT OF A SUPERFICIAL FOOT OF VARIOUS METALS.

Thickness in Inches.	Wrought Iron.	Cast Iron.	Steel.	Copper.	Brass.	Lead.	Zinc.	Thickness in Inches.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
1-16th.	2·526	2·344	2·552	2·891	2·374	3·708	2·344	1-16th.
1-8th.	5·052	4·687	5·104	5·781	5·469	7·417	4·687	1-8th.
3-16ths.	7·578	7·031	7·656	8·672	8·203	11·125	7·031	3-16ths.
1-4th.	10·104	9·375	10·208	11·563	10·938	14·833	9·375	1-4th.
5-16ths.	12·630	11·719	12·760	14·453	31·672	18·542	11·719	5-16ths.
3-8ths.	15·156	14·062	15·312	17·344	16·406	22·250	14·062	3-8ths.
7-16ths.	17·682	16·406	17·865	20·234	19·141	25·958	16·406	7-16ths.
1-half.	20·208	18·750	20·417	23·125	21·875	29·667	18·750	1-half.
9-16ths.	22·734	21·094	22·969	26·016	24·609	33·375	21·094	9-16ths.
5-8ths.	25·260	23·437	25·521	28·906	27·344	37·083	23·437	5-8ths.
11-16ths.	27·786	25·718	28·073	31·797	30·078	40·792	25·781	11-16ths.
3-4ths.	30·312	28·125	30·625	34·688	32·813	44·500	28·125	3-4ths.
13-16ths.	32·839	30·469	33·177	37·578	35·547	48·208	30·469	13-16ths.
7-8ths.	35·365	32·812	35·729	40·469	38·281	51·917	32·812	7-8ths.
15-16ths.	37·891	35·156	38·281	43·359	41·016	55·625	35·156	15-16ths.
1 inch	40·417	37·500	40·833	46·250	43·750	59·333	37·500	1 inch.

WEIGHT IN PARTS OF A POUND OF A SPHERE 1 IN. DIAM. OF VARIOUS METALS.

Brass Cast.	Bronze.	Copper Hammered.	Iron Cast.	Iron Wrought.	Steel.	Lead.	Tin.	Zinc.
·156	·159	·167	·135	·145	·147	·214	·139	·133

HOOP IRON.

Weight of 10 *Lineal Feet.*

Width in Inches and Parts.	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3
No. of Gauge .	21	20	19	18	17	16	15	15	14	13	13	12	11	11
Weight in lbs. & Decimal Parts.	·685	·885	1·24	1·60	2·05	2·73	3·40	3·72	4·72	6·06	6·83	8·96	10·85	11·84

TAPER ANGLE IRON, OF EQUAL SIDES.

Length of Sides in Inches.	Thickness of Edges.	Thickness of Root.	Weight of One Lineal Foot in lbs. and Decimal Parts.
4	1/2 in.	5/8 in.	14·0
3	1/2	5/8	10·375
2 3/4	7/16	9/16	8·25
2 1/2	3/8	1/2	6·5
2 1/4	5/16 full	7/16	5·0
2	1/4 full	5/16 full	3·875
1 3/4	1/4	5/16	3·25
1 1/2	1/4 bare	5/16 bare	2·625

TAPER T-IRON.

Width of Top Table in Inches.	Total Depth in Inches.	Thickness of Top Table at Root.	Thickness of Top Table at Edges.	Uniform Thickness of Rib.	Weight of One Lineal Foot in lbs.
3	3 1/4	1/2 in.	3/8 in.	7/16 in.	8·0
3	2 5/8	7/16	3/8	1/2	8·0
2	3	7/16	5/16	5/16	5·25
2 1/2	2 1/2	5/8	1/2	1/2 full	6·5
2	1 1/2	3/8	5/16	3/8	3·5
2	1 1/2	5/16	1/4	1/4	2·875

WEIGHT OF CORRUGATED IRON ROOFING.

B.W. Gauge.		Size of Sheets.				Per Square.		Super. Feet per ton.
16	..	6 feet	×	2 feet to 8 feet	× 3 feet	×	3 1/8 cwt.	.. 800
18	..	6 ,,	×	2 ,, 8 ,,	× 3 ,,	×	2 1/4 ,,	.. 1000
20	..	6 ,,	×	2 ,, 8 ,,	× 3 ,,	×	1 3/4 ,,	.. 1250
22	..	6 ,,	×	2 ,, 7 ,,	× 2 1/2 ,,	×	1 1/2 ,,	.. 1550
24	..	6 ,,	×	2 ,, 7 ,,	× 2 1/2 ,,	×	1 1/4 ,,	.. 1880
26	..	6 ,,	×	2 ,, 7 ,,	× 2 1/2 ,,	×	1 ,,	.. 2170

WEIGHT IN POUNDS OF NUTS AND BOLT-HEADS.

Diameter of Bolt in Inches.	1/4	3/8		5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/2	3
Weight of Hexagon Nut and Head.	·017	·057	·128	·267	·430	·730	1·10	2·14	3·77	5·62	8·75	17·2	28·8
Weight of Square Nut and Head.	·021	·070	·164	·321	·553	·882	1·31	2·56	4·42	7·00	10·50	21·0	36·4

WHITWORTH'S SCREWS WITH ANGULAR THREADS.

Diameter in Inches.	Number of Threads per Inch.	Diameter in Inches.	Number of Threads per Inch.	Diameter in Inches.	Number of Threads per Inch.
$\frac{1}{8}$	40	$1\frac{3}{8}$	6	3	$3\frac{1}{2}$
$\frac{3}{16}$	24	$1\frac{1}{2}$	6	$3\frac{1}{4}$	$3\frac{1}{4}$
$\frac{1}{4}$	20	$1\frac{5}{8}$	5	$3\frac{1}{2}$	$3\frac{1}{4}$
$\frac{5}{16}$	18	$1\frac{3}{4}$	5	$3\frac{3}{4}$	3
$\frac{3}{8}$	16	$1\frac{7}{8}$	$4\frac{1}{2}$	4	3
$\frac{7}{16}$	14	2	$4\frac{1}{2}$	$4\frac{1}{4}$	$2\frac{7}{8}$
$\frac{1}{2}$	12	$2\frac{1}{8}$	$4\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{7}{8}$
$\frac{5}{8}$	11	$2\frac{1}{4}$	4	$4\frac{3}{4}$	$2\frac{3}{4}$
$\frac{3}{4}$	10	$2\frac{3}{8}$	4	5	$2\frac{3}{4}$
$\frac{7}{8}$	9	$2\frac{1}{2}$	4	$5\frac{1}{4}$	$2\frac{5}{8}$
1	8	$2\frac{5}{8}$	4	$5\frac{1}{2}$	$2\frac{5}{8}$
$1\frac{1}{8}$	7	$2\frac{3}{4}$	$3\frac{1}{2}$	$5\frac{3}{4}$	$2\frac{1}{2}$
$1\frac{1}{4}$	7	$2\frac{7}{8}$	$3\frac{1}{2}$	6	$2\frac{1}{2}$

Angle of threads 55° in every instance.

The threads do not intersect at their sides, but are rounded off one-sixth both at top and bottom, making their depth equal to two-thirds of the pitch.

The number of threads to the inch in square-threaded screws is generally half the number of those in angular-threaded screws, and the depth equal to the space between the threads.

WEIGHT OF CHAINS.

Diameter of Link in inches.	Weight per Lineal Foot in lbs.	Diameter of Link in inches.	Weight per Lineal Foot in lbs.	Diameter of Link in inches.	Weight per Lineal Foot in lbs.
$\frac{3}{16}$	·33	$\frac{3}{4}$	5·33	$1\frac{5}{16}$	16·00
$\frac{1}{4}$	·63	$\frac{13}{16}$	6·16	$1\frac{3}{8}$	17·66
$\frac{5}{16}$	·91	$\frac{7}{8}$	7·16	$1\frac{7}{16}$	19·25
$\frac{3}{8}$	1·33	$\frac{15}{16}$	8·16	$1\frac{1}{2}$	20·83
$\frac{7}{16}$	1·50	1	9·33	$1\frac{5}{8}$	24·17
$\frac{1}{2}$	2·33	$1\frac{1}{16}$	10·50	$1\frac{3}{4}$	28·33
$\frac{9}{16}$	3·00	$1\frac{1}{8}$	11·83	$1\frac{7}{8}$	32·50
$\frac{5}{8}$	3·67	$1\frac{3}{16}$	13·16	2	38·33
$\frac{11}{16}$	4·50	$1\frac{1}{4}$	14·50		

To Find the Safe Load on Chains.

$$\frac{(\text{Diam. of link in eighths of an inch})^2}{8} = \text{safe load in tons.}$$

$$\sqrt{(8 \times \text{weight to be raised})} = \text{diam. of link in eighths of an inch.}$$

WEIGHT AND STRENGTH OF ROUND ROPES OF HEMP AND WIRE.

Hemp.			Iron Wire.			Steel Wire.		
Girth or Circumference in Inches	Weight per Fathom of Six Feet in lbs.	Breaking Weight in Tons.	Girth or Circumference in Inches	Weight per Fathom of Six Feet in lbs.	Breaking Weight in Tons.	Girth or Circumference in Inches	Weight per Fathom of Six Feet in lbs.	Break'g Weight in Tons.
¾	·15	⅛	¾	·56	⅞	1	1	2½
1	·26	⅕	1	1	1½	1¼	1¼	3¾
1½	·59	½	1½	1½	3¼	1⅜	1½	4¾
2	1·04	⅘	1⅝	2	4	1½	1¾	5½
2½	1·70	1¼	1¾	2½	4½	1⅝	2	6½
2¾	2·00	1½	1⅞	3	5¼	1¾	2¼	7½
3	2·34	1⅘	2	3½	6	1⅞	2¾	8¾
3½	3·19	2½	2⅛	4	6¾	2	3¼	10
3¾	3·66	2⅘	2¼	4½	7½	2⅛	3¾	11¼
4	4·16	3⅕	2⅜	5	8¼	2¼	4¼	12½
4½	5·27	4	2½	5½	9¼	3⅜	4¾	14
5	6·50	5	2⅝	6	10¼	2½	5¼	15½
5½	7·86	6	2¾	6½	11¼	2⅝	5¾	17¼
6	9·36	7¼	2⅞	7	12¼	2¾	6¼	19
6½	11·00	8½	3	7½	13½	2⅞	6¾	20½
7	12·74	9¾	3⅛	8	14½	3	7¼	22½
7½	14·63	11¼	3¼	8½	16	3⅛	7½	24½
8	16·64	12¾	3⅜	9	17	3¼	8	26½
8½	18·78	14½	3½	10	18½	3⅜	8	28½
9	21·06	16¼	3⅝	11	19¾	3½	10	30½
9½	23·46	18	3¾	12	21	3¾	12	35
10	26·00	20	3⅞	13	22½	4	15	40
10½	28·66	22	4	14	24			
11	31·46	24¼	4¼	15	27			
11½	34·38	26½	4⅜	16	28¾			
12	37·44	29	4½	18	30¼			
			4⅝	20	32			
			5	25	38			
			5½	32	45½			
			6	38	54			

To find the Breaking Weight of Round Ropes of Hemp, Iron Wire and Steel Wire.

Hemp $\frac{(\text{circum. ins.})^2}{5}$ = breaking weight in tons.

Iron wire (circum. ins.)^2 × 1·5 = breaking weight in tons.

Steel wire (circum. ins.)^2 × 2·5 = breaking weight in tons.

Factor of safety for hemp, iron, and steel ropes = $\frac{1}{6}$.

To find the Weight of Hemp Ropes.

(Circum. ins.)^2 × 26 = weight in lbs. per fathom.

ALLOYS OF METALS.

Yellow brass, 2 parts copper, 1 zinc.
Rolled brass, 32 parts copper, 10 zinc, 1·5 tin.
Brass casting, common, 25 parts copper, 2 zinc, 4·5 tin.
Gun metal, 8 parts copper, 1 tin.
Copper Flanges for pipes, 9 parts copper, 1 zinc, 0·26 tin.
Bell metal, 3 parts copper, 1 tin.

IRON TO RESIST THE ACTION OF FIRE.

The following mixture of iron is recommended for fire bars, furnace plates, gas retorts (iron) and any other ironwork required to resist the action of fire :—

80 per cent. Ridsdale.
20 per cent. Siemens Steel Scrap.

This is said to make a kind of pyrostatic iron, the high fusion point being due to the small percentage of carbon present in the mixture.

TABLE

Of the Velocity and Force of the Wind.

Miles per Hour.	Feet per Second.	Pressure in lbs. per Square Foot.	Description.
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·4	·044	
4	5·87	·079	Gentle breeze.
5	7·33	·123	
10	14·67	·492	Pleasant breeze.
15	22·0	1·107	
20	29·34	1·968	Brisk gale.
25	36·67	3·076	
30	44·01	4·429	High wind.
35	51·34	6·027	
40	58·68	7·873	Very high wind.
45	66·01	9·996	
50	73·35	12·300	Storm or tempest.
60	88·02	17·718	Great storm.
70	102·71	24·153	
80	117·36	31·490	Hurricane.
100	146·7	49·200	

The pressure or force of the wind is as the square of its velocity.

The square of the velocity of the wind in feet per second × ·002288 = pressure in lbs. per square foot.

The wind pressure upon a cylindrical surface is one-half, and on a spherical surface one-fourth that which is exerted on a flat surface.

SPECIFIC GRAVITY AND WEIGHT OF VARIOUS SUBSTANCES.

Name of Substance.	Specific Gravity and Weight per Cb. Ft. in Ounces.	Weight per Cub. Foot in lbs. Avoirdupois.
Alcohol, pure	790	49·38
Ash (timber)	752	47
Asphalt, prepared	2,496	156
Basalt	2,992	187
Bath stone	1,792	112
Beech	688	43
Birch	704	44
Bitumen	992	62
Boxwood	960	60
Brass, cast	8,240	515
„ wire	8,480	530
Brick	2,080	130
Brickwork	1,792	112
Cement, Portland	1,424	89
„ Roman	960	60
Chalk	2,368	148
Charcoal, Oak	336	21
Clay	1,920	120
Clay puddle	2,560	160
Coal, anthracite, solid	1,280	80
„ bituminous	1,200	75
„ cannel, Scotch	1,248	78
„ „ Wigan	1,280	80
„ „ N'castle	1,312	82
„ stored in usual way	832	52
Coke from coking ovens	800	50
„ from gas-works slaked	515	32·2
„ from gas-works unslaked	448	28
Concrete	1,920	120
Copper, cast	8,640	540
„ sheet and wire	8,800	550
Cork	240	15
Earth, loam	1,600	100
Ebony	1,200	75
Elm	560	35
Fir, red pine and spruce	560	35
„ American	464	29
„ larch	544	34
Fire-Clay, natural	2,400	150
„ burned in blocks	2,080	130
Flag, Yorkshire	2,288	143
Flint	2,624	164
Freestone	2,240	140
Glass, crown	2,496	156
„ plate	2,880	180
„ flint	2,992	187
Gold, pure	19,360	1,210
„ standard	17,728	1,108
Granite	2,688	168
Gravel	1,840	115
Grindstone	2,096	131
Gun metal	8,784	549
Gypsum	2,304	144
Ice	908	56·75
Iron, cast	7,168	448
Iron, wrought	7,680	480
Lead	11,392	712
„ white	3,168	198
Limestone, lias	2,496	156
„ magnesian	2,848	178
Lime, quick	864	54
Mahogany, Honduras	640	40
„ Spanish	720	45
Maple	784	49
Marble	2,720	170
Marl	1,728	108
Masonry	2,240	140
Mercury	13,584	849
Mortar	1,760	110
Mud	1,600	100
Naphtha	848	53
Oak, English	800	50
„ American, red	864	54
Oil, linseed	944	59
„ olive	912	57
„ whale (train)	928	58
„ sperm	880	55
„ tallow	896	56
„ colza	912	57
Paving	2,560	160
Peat	1,280	80
Pebble stone	2,704	169
Petroleum	880	55
Pitch	1,152	72
Platinum, pure	19,520	1,220
„ hammered	20,480	1,280
„ wire	20,800	1,300
Portland stone	2,096	131
Quartz	2,640	165
Sand, damp	1,888	118
„ dry	1,440	90
Sandstone	2,528	158
Shale	2,592	162
Shingle	1,520	95
Silver, pure	10,480	655
„ standard	10,528	658

SPECIFIC GRAVITY AND WEIGHT OF VARIOUS SUBSTANCES—*Continued.*

Name of Substance.	Sp. Gr. and Weight per Cb. Ft. in Ounces.	Weight per Cub. Foot in lbs. Avoirdupois.	Name of Substance.	Sp. Gr. and Weight per Cb. Ft. in Ounces.	Weight per Cub. Foot in lbs. Avoirdupois.
Slate	2,880	180	Trap	2,720	170
Snow	128	8	Water, pure	1,000	62·5
Steel	7,840	490	,, sea	1,024·8	64·05
Sulphur	2,000	125	Whinstone	2,752	172
Sycamore	592	37	Willow.	448	28
Tar	1,040	65	Yew	800	50
Tile	1,792	112	Yorkshire flag . . .	2,288	143
Tin	7,360	460	Zinc	7,040	440
	Mean of the whole earth			5,664	354

MISCELLANEOUS ARTICLES.

Bale of flax (Russia)	5 to 6 cwt.
Barrel bulk	5 cubic feet.
Barrel of tar	26¼ gallons.
Battens	Boards 7 inches wide.
Bushel of coal	80 lbs.
Bushel of coke	45 ,,
Cable's length	240 yards.
Cask of black lead	11½ cwt.
Chaldron of coal.	25½ ,,
,, coke	12½ to 15 cwt.
Cord of wood	128 cubic feet.
Deals.	Boards 9 inches wide.
Dozen	12 articles.
Faggot of steel	120 lbs.
Fodder of lead	19½ cwt.
Gross.	12 doz.
Hundred of deals	120 in number.
,, nails	120 ,,
Keel of coals	21 tons 4 cwt.

Load of bricks	500 bricks.
,, inch boards	600 square feet.
,, 2-inch planks	800 square feet.
,, lime	32 bushels.
,, new hay	19 cwt. 32 lbs.
,, old hay	18 ,,
,, straw	11 ,, 64 ,,
,, sand	36 bushels.
,, squared timber	50 cubic feet.
,, unhewn	
,, tiles	1000 tiles.
Mat of flax (Dutch)	126 lbs.
Pig of ballast	56 ,,
Planks	Boards 12 inches wide.
Quire of paper	24 sheets.
Ream of paper	20 quires, or 480 sheets.
Roll of parchment	60 skins.
Sack of coals	224 lbs.
Score	20 articles.
Sheet of paper folded into—	
2 leaves is termed	folio size.
4 ,, ,,	4to, or quarto.
8 ,, ,,	8vo, or octavo.
12 ,, ,,	12mo, or duodecimo.
16 ,, ,,	16 mo. ,,
18 ,, ,,	18 mo. ,,
24 ,, ,,	24 mo. ,,
48 ,, ,,	48 mo. ,,
Square of planking	100 superficial feet.
Thousand of nails	1200 nails.
Ton shipping	40 cubic feet.
Truss of old hay	56 lbs.
,, new hay	60 ,,
,, straw	36 ,,

OFFICE MEMORANDA.

Books Required in the Keeping of a Gas Company's Accounts.

1. Ledger (general).

2. Cash Book (general).

3. Gas Register, or Ledger, sometimes called "The Consumers' Ledger."

4. Mill Register, or Ledger.
   This book is devoted to the accounts of all the largest consumers, such as millowners, and the proprietors of other large establishments of any kind where the consumption of gas is heavy. They are handier classed together by themselves, than mixed up with smaller consumers.

5. Removals Book.
   In this book is kept an account of all changes of residence that have taken place amongst consumers during each quarter, the substitution of meters, and the consumption of gas by temporary consumers, &c. It is a most useful record, and prevents confusion by interlineations in the regular register.

6. Quarterly Summary.
   The several pages in the three foregoing books are added up and then brought together here, quarterly, in order to ascertain the total consumption, amount due, &c. By means of this book it is easy to compare the totals of the different quarters during a number of years.

7. Journal,
   Containing entries of all goods sold from the works, with the exception of gas. Separate columns should be arranged for "Fittings, &c.," "Residual Products," "Miscellaneous," and "Total." At the end of each quarter the separate amounts of all accounts remaining unpaid are transferred to the

8. Arrears Fittings, &c., Book,
   Which is entered up at the end of every quarter, and shows the amount remaining due (arrears included) for Fittings, Residual Products, and Miscellaneous.

9. Daily Receipt (Cash) Book,
   In which is entered the amount of each separate payment made to the company on account of "Gas," "Meter-Rents," "Fittings, &c.," "Residual Products," and other miscellaneous items.

10. Stock-Taking Books,
    For taking the quarterly stock of gas consumed through each meter. Two or more are always required, according to the number of consumers. The one used (we will suppose) on Monday is left at the office that night to be entered up into the Register by the clerk on the day following; and so on alternately.

11. Black Book,
    In which a record of all bad debts is kept.

12. Collector's Book.
    In some cases checks only are used with counterfoil.

13. Receiving Book,
    In which all delivery notes for goods received by the company are copied daily. The regular invoice, when received, is checked by this book.

14. Wages and Time Book,
    Containing, in separate columns, a daily account of the number of hours worked by each man, the kind of work, and the place where employed, with the amount due as wages at the end of each week.

15. Stores Book, A.

16. Stores Book, B.
    In the one is kept a record of goods *sold* out of stock, and in the other of goods *used* out of stock for *repairs and extension*

of plant. The one may be said to relate to *revenue;* the other chiefly to *capital.*

17. Stores Ledger,
    Into which the entries in the previous two books are posted to the *credit* of the several accounts (such as "Meters," "Lead Pipe," "Wrought-iron Fittings," &c.), and the items from the several invoices are posted to the *debit* of the several accounts. At the end of each half year the balance of each account represents the stock on hand. This latter is proved to be correct or otherwise by the result of the actual stock-taking.

18. Carbonizing Book—Daily and Weekly Statements,
    Containing a record of the state of the station-meter taken twice in the 24 hours (in large works the state of the meter is recorded every hour); the quantity of coal and cannel used daily, the production of gas per ton, and the total daily production; the number of benches at work, stokers, &c. Each page serves for a week, and is then added up; an additional line is left at the foot of the page, on which is entered, for comparison, the particulars of the total of the corresponding week of the previous year.

19. Public Lamp Register,
    Gives particulars of the number of lamps lighted each night; the hours of lighting and extinguishing; the hours burning per lamp, the total hours burning; a column into which the number of hours, weekly, can be added, and another for remarks.

20. Test Register,
    For noting the results of the different tests of the illuminating power and purity of the gas.

21. Shareholders' Register and Address Book.

22. Seal Register and Dividend List.

23. Register of Calls.

24. Register of Transfers.

25. Transfer Certificate Book,
Containing certificates of the registration of shares, to be torn out, leaving counterfoil behind.

26. Invoice Book,
With blank leaves, into which are gummed all invoices for goods received.

27. Minute Book.
A lettered index at the beginning of this book is handy.

A few other account-books of a less important character may be useful; but the above are indispensable in a well-regulated gas company.

Discount for Early Payment of Gas Bills.

The custom of allowing discount to consumers on gas bills paid either during the first month after the expiration of a quarter, or within a period of 21 or 30 days from the date of the delivery of the account, is very general amongst gas companies.

The most common allowance is at the rate of 10 per cent. on the amount due for gas consumed (excluding the meter-rent), but the premium varies throughout the country from 5 to 20 per cent.; some companies adopting a graduated scale of discounts according to the quarterly consumption.

The practice, wherever adopted, has been found highly beneficial, saving labour in collecting, and reducing the percentage of bad debts.

FORMS.

Renouncement of Proposed New Issue on the Transfer of Old Shares.

I, John Thompson, of Tipping Street, Newcastle, hereby renounce my right to any of the new Shares about to be issued by the ——— Gas Company, in favour of William Jones, of Broad Street, Manchester.

(Signed) JOHN THOMPSON.

To the Secretary
of the ——— Gas Company.

Jan. 1, 18—

Renunciation of Shares Newly Allotted.

I, John Wilson, of Birmingham, being the holder [*or* proprietor] of —— Shares in the ——— Gas Company, do hereby renounce the same to and in favour of William Jackson, of Bristol. And I, the said William Jackson, hereby agree to accept and take the said Shares, subject to the conditions on which they are allotted. Dated this —— day of ———, One thousand eight hundred and ——

Signed by the said John Wilson in the presence of	JOHN WILSON.
(*Here Witness signs.*)	
Signed by the said William Jackson in the presence of	WILLIAM JACKSON.
(*Here Witness signs.*)	

Declaration for Loss of Sealed Share Certificates.

I, ———, of ———, do hereby solemnly and sincerely declare that I am possessed of and entitled to——— in the ——— Company, ———, and that the said ——— are *bonâ fide* my property, and that they are not pledged or assigned to any person or persons whomsoever for money advanced thereon, or for any consideration whatever. And I further declare that I have made diligent search for the ———, and can nowhere find the same. And I make this solemn declaration conscientiously believing the same to be true, and by virtue of the provisions of an Act made and passed in the 5th and 6th years of the reign of His late Majesty King William the Fourth, intituled "An Act to repeal an Act of the present Session of Parliament, intituled 'An Act for the more effectual abolition of Oaths and Affirmations taken and made in various departments of the State, and to substitute declarations in lieu thereof,' and for the more entire suppression of voluntary and extra judicial Oaths and Affidavits, and to make other provisions for the abolition of unnecessary Oaths."

Declared at ——, this —— day of ———, One thousand eight hundred and ——, before me.

[The above Declaration is to be made before a Commissioner to administer Oaths in Chancery in England. Any person making a false Declaration is declared guilty of a misdemeanour.]

Indemnity for Loss of Share Certificates or Dividend Warrant.

——— Company.

Whereas ———, in the Company called the ———, numbered ——, being the property of ———, the undersigned, h— by accident been lost or destroyed, and the said Company have consented to give ———, on being indemnified for so doing. Now, in consideration of the said Company so granting to me, the said ———, a ———, we the undersigned ——— and ——— do hereby severally and respectively undertake and agree to save harmless and keep indemnified the Directors for the time being of the said Company of and from all losses, damages, and expenses which they, any or either of them, may sustain, incur, or be put unto, for or in consequence of their so granting such new ——— ; and also from and against all claim or claims to be at any time hereafter made upon the said Company for or in respect of the original ——— by any person or persons whomsoever.

Dated this ——— day of ———, One thousand eight hundred and ——.

Authority to Pay Dividends.

——— Company,

——— 18—

Payment of Dividends.

I, the undersigned, ———, of ———, being a shareholder of and in the undertaking called the ——— Company, do hereby request that all Dividends and Interest due to me on the Stock or Shares now registered, or that may hereafter be registered in my name may be paid to ———, of ———, until further notice, whose receipt shall be a sufficient discharge to the Company for the payment of the same.

Signature ———

Date ———

Certificate Showing that Income-Tax has been Deducted.

This is to certify that on paying to John Brown the sum of £45, being the amount of one year's Dividend (*or*, one half year's Dividend, as the case may be) on Shares (*or* Stock) to December 31st, 18——, I deducted for Income-Tax the sum of 18s. 9d.

Pro the A————B————Gas Company,
WILLIAM JONES,
Secretary.

Form of Proxy.

A.B., one of the proprietors of "The ——— Company," doth hereby appoint C.D., of ———, to be the proxy of the said A.B., in his absence to vote in his name upon any matter relating to the undertaking proposed at the meeting of the proprietors of the said Company, to be held on the —— day of —— next, in such manner as he the said C.D. doth think proper. In witness whereof the said A.B. hath hereunto set his hand [*or, if a corporation*, say, the common seal of the corporation], the —— day of ——, One thousand eight hundred and ——.

TERMS FOR LEASES, ETC.

England and Ireland.		*Scotland.*	
Lady Day . . .	March 25th.	Candlemas . .	Feb. 2nd.
Midsummer . .	June 24th.	Whitsunday . .	May 15th.
Michaelmas . .	Sept. 29th.	Lammas . . .	August 1st.
Christmas . . .	Dec. 25th.	Martinmas . .	Nov. 11th.

When a Scottish term falls on Sunday, the Monday following is considered term day.

LAW TERMS.

England and Ireland.

Hilary or Lent . .	Begins, Jan. 11th. .	Ends, Jan. 31st.
Easter	,, April 15th. .	,, May 8th.
Trinity	,, May 22nd. .	,, June 12th.
Michaelmas . . .	,, Nov. 2nd.. .	,, Nov. 25th.

Scotland.

Candlemas . . .	Begins, Jan. 15th.	. Ends, Feb. 3rd.
Whitsunday . . .	,, May 12th.	. ,, June 2nd.
Lammas	,, June 17th.	. ,, July 5th.
Martinmas . . .	,, Nov. 24th.	. ,, Dec. 20th.

SIZES OF DRAWING PAPER.

	Ft. In.		Ft. In.		Ft. In.		Ft. In.
Antiquarian . .	4 4	×	2 7	Double Crown .	3 6	×	1 8
,, extra	4 8	×	3 4	Imperial . . .	2 6	×	1 10
Double Elephant	3 4	×	2 3	Super Royal .	2 3	×	1 7
Atlas	2 10	×	2 2	Royal . . .	2 0	×	1 7
Columbia . .	2 10	×	1 11	Medium . . .	1 10	×	1 5
Elephant . .	2 3¾	×	1 10¼	Demy . . .	1 8	×	1 3

TABLE OF COLOURS.

Used in Mechanical and Architectural Drawing.

Work.	Colour.
Brickwork in plan or section .	Carmine or crimson lake.
Brickwork in elevation . . .	Venetian red or crimson lake mixed with burnt sienna.
Brickwork to be removed by alterations	Burnt umber.
Concrete works	Sepia with darker markings.
Clay	Burnt umber.
Earth	Burnt umber.
Flintwork	Prussian blue.
Granite	Purple madder or pale Indian ink.
Stone generally	Yellow ochre or pale sepia.
Slate	Indigo and lake or Prussian blue.
English timber (oak excepted) .	Raw sienna.
Oak	Burnt sienna or Vandyke brown.
Fir and other light timber . .	Indian yellow or raw sienna.
Mahogany	Indian red.
Cast iron	Payne's grey or neutral tint.
Wrought iron	Prussian blue.
Steel, bright	Indigo with a little lake.
Brass	Gamboge or Roman ochre.
Gun metal	Dark cadmium.
Lead	Pale Indian-ink, tinged with indigo.
Meadow land	Hooker's green.
Sky effects	Cobalt blue.

The presence of any slight greasiness, preventing the laying on of the colours evenly, may be counteracted in its effects by dissolving a little prepared ox-gall in the water with which the colours are mixed. The brush should always be used in mixing colours; the latter being rubbed in separate divisions of the slab.

EPITOME OF MENSURATION.

Of the Circle, Cylinder, and Sphere.

The areas of circles are to each other as the squares of their diameters.

The diameter of a circle being 1, its circumference equals 3·1416.

The diameter of a circle multiplied by 3·1416 equals its circumference.

The diameter of a circle is equal to ·31831 of its circumference.

The square of the diameter of a circle being 1, its area equals ·7854.

The diameter of a circle squared and multiplied by ·7854 equals its area.

The internal circumference of a cylinder multiplied by its length or height equals its concave surface.

The area of the end of a cylinder multiplied by its length equals its solid contents.

The area of the internal diameter of a cylinder multiplied by its depth equals its cubical capacity.

The square of the diameter of a sphere multiplied by 3·1416 equals its convex surface.

The cube of the diameter of a sphere multiplied by ·5236 equals its solid contents.

The capacity of a cylinder 1 foot in diameter and 1 foot in length equals 4·895 imperial gallons.

The capacity of a cylinder 1 inch in diameter and 1 foot in length equals ·034 of an imperial gallon.

The capacity of a cylinder 1 inch in diameter and 1 inch in length equals ·002832 of an imperial gallon. Hence—

The capacity of any other cylinder in imperial gallons is obtained by multiplying the square of its diameter by its length, and by the number of imperial gallons contained in the unity of its measurement.

The capacity of a sphere 1 foot in diameter equals 3·263 imperial gallons.

The capacity of a sphere 1 inch in diameter equals ·001888 of an imperial gallon. Hence—

The capacity of any other sphere in imperial gallons is obtained by multiplying the cube of its diameter by the number of imperial gallons contained in the unity of its measurement.

Of the Square, Rectangle, and Cube.

The side of a square equals the square root of its area.

The area of a square equals the square of one of its sides.

The diagonal of a square equals the square root of twice the square of its side.

The side of a square is equal to the square root of half the square of its diagonal.

The side of a square equal to the diagonal of a given square contains double the area of the given square.

The area of a rectangle equals its length multiplied by its breadth.

The length of a rectangle equals the area divided by the breadth; or the breadth equals the area divided by the length.

The side or end of a rectangle equals the square root of the sum of the diagonal and opposite side to that required, multiplied by their difference.

The diagonal in a rectangle equals the square root of the sum of the square of the base and perpendicular.

The solidity of a cube equals the area of one of its sides multiplied by the length or breadth of one of its sides.

The length or breadth of a side of a cube equals the cube root of its solidity.

The capacity of a 12-inch cube equals 6·232 imperial gallons.

Of Triangles and Polygons.

The sum of the squares of the two given sides of a right-angled triangle is equal to the square of the hypotenuse.

The difference between the squares of the hypotenuse and given side of a right-angled triangle is equal to the square of the required side.

The area of a triangle equals half the product of the base multiplied by the perpendicular height.

The side of any regular polygon multiplied by its apothegm, or perpendicular, and by the number of its sides, equals twice the area.

Of Ellipses, Cones, and Frustums.

The square root of half the sum of the squares of the two diameters of an ellipse, multiplied by 3·1416, equals its circumference.

The product of the two axes of an ellipse, multiplied by ·7854, equals its area.

The solidity of a cone equals one-third of the product of its base multiplied by its altitude or height.

The squares of the diameters of the two ends of the frustum of a cone added to the product of the two diameters, and that sum multiplied by its height and by ·2618, equal its solidity.

Table of Common Fractional Parts and Equivalent Decimals.

Common Fractional Parts.	Decimals.	Common Fractional Parts.	Decimals.	Common Fractional Parts.	Decimals.
1-100th	·01	9-14ths	·6428	7-10ths	·7
1-90th	·0111	11-14ths	·7857	9-10ths	·9
1-80th	·0125	13-14ths	·9285	1-9th	·1111
1-70th	·0143	1-13th	·077	2-9ths	·2222
1-60th	·0166	2-13ths	·1538	4-9ths	·4444
1-50th	·02	3-13ths	·2307	5-9ths	·5555
1-40th	·025	4-13ths	·3076	7-9ths	·7777
1-30th	·0333	5-13ths	·3846	8-9ths	·8888
1-20th	·05	6-13ths	·4615	1-8th	·125
1-19th	·0526	7-13ths	·5384	3-8ths	·375
1-18th	·0555	8-13ths	·6153	5-8ths	·625
1-17th	·0588	9-13ths	·6923	7-8ths	·875
1-16th	·0625	10-13ths	·7692	1-7th	·143
3-16ths	·1875	11-13ths	·8461	2-7ths	·2857
5-16ths	·3125	12-13ths	·923	3-7ths	·4285
7-16ths	·4375	1-12th	·0833	4-7ths	·5714
9-16ths	·5625	5-12ths	·4166	5-7ths	·7142
11-16ths	·9875	7-12ths	·5833	6-7ths	·8571
13-16ths	·8125	11-12ths	·9166	1-6th	·1666
15-16ths	·9375	1-11th	·0909	5-6ths	·833
1-15th	·0666	2-11ths	·1818	1-5th	·2
2-15ths	·1333	3-11ths	·2727	2-5ths	·4
4-15ths	·2666	4-11ths	·3636	3-5ths	·6
7-15ths	·4666	5-11ths	·4545	4-5ths	·8
8-15ths	·5333	6-11ths	·5454	1-4th	·25
11-15ths	·7333	7-11ths	·6363	3-4ths	·75
13-15ths	·8666	8-11ths	·7272	1-3rd	·3333
14-15ths	·9333	9-11ths	·8181	2-3rds	·6666
1-14th	·0714	10-11ths	·909	1-half	·5
3-14ths	·2142	1-10th	·1	1	1
4-14ths	·2857	3-10ths	·3		

ARITHMETICAL AND ALGEBRAICAL SIGNS.

$=$ The sign of Equality, and signifies *equal to*, as 2 added to $3 = 5$.
$+$,, Addition ,, *plus* or *more*, as $4 + 6 = 10$.
$-$,, Subtraction ,, *minus* or *less*, as $6 - 4 = 2$.
$\times$,, Multiplication ,, *multiplied by*, as $5 \times 3 = 15$.
$\div$,, Division ,, *divided by*, as $8 \div 4 = 2$.
or $\frac{8}{4} = 2$

: : : : ,, Proportion, : signifies *is to*, or *to*, : : signifies *so is*. Thus, 2 : 3 : : 4 : 6 signifies that as 2 is to 3 so is 4 to 6.

Evolution, or the Extraction of Roots.

$\sqrt{}$ The sign of the Square Root (termed the Radical sign), as $\sqrt{16} = 4$, *i.e.*, the square root of 16 is equal to 4.
$\sqrt[3]{}$,, Cube Root, as $\sqrt[3]{64} = 4$, *i.e.*, the cube root of 64 is equal to 4.
$\sqrt[4]{}$,, Bi-quadrate, or fourth Root, $\sqrt[4]{16} = 2$.

Involution, or the raising of Powers.

4^2 signifies to be squared, as $4^2 = 16$. The small figure is termed the Index or Exponent.
4^3 ,, to be cubed, as $4^3 = 64$.
—— A vinculum placed over two or more figures, thus $\overline{3 + 5}$, signifies that they are to be taken as one quantity. Thus:
$\overline{3 + 5} \times 4 = 32$, signifies that 3 plus 5 multiplied by 4 = 32, and
$\sqrt{5^2 - 3^2} = 4$, signifies that 5 squared, minus 3 squared, and the square root of the remainder = 4, and
$\sqrt[3]{\frac{20 \times 12}{30}} = 2$, signifies that 20 multiplied by 12, divided by 30, and the cube root of the quotient = 2, and
$\frac{\overline{24 \times 6 + 12 \times 3} \times 4}{12} = 60$, signifies that 24 multiplied by 6, and 12 multiplied by 3, added together, multiplied by 4 and divided by 12, the quotient = 60.

[ ] ( ) Brackets; *e.g.* $12 - [3 + (4 \times 2)] = 1$, signify that the product of 4, multiplied by 2, added to 3, and the total subtracted from 12, leaves 1.

$\therefore$ is used to signify the word *therefore*.

$\because$ is used to signify the word *because*, or *since*.

? is used in the Chain Rule to signify *how many*.

APPROXIMATE MULTIPLIERS FOR FACILITATING CALCULATIONS.

Square inches × ·007 = square feet.
Square feet × ·111 = square yards.
Square yards × ·0002067 = statute acres.
Square yards × ·000000323 = square miles.
Statute acres × ·0015625 = square miles.
Square links × ·4356 = square feet.
Square feet × 2·3 = square links.
Square feet × 183·346 = circular inches.
Circular inches × ·00456 = square feet.
Links × ·22 = yards.
Links × ·66 = feet.
Feet × 1·5 = links.
Cubic inches × ·00058 = cubic feet.
Cubic inches × ·01638 = litres.
Cubic feet × ·037 = cubic yards.
Cubic feet × 2200 = cylindrical inches.
Cylindrical inches × ·0004546 = cubic yards.
Cylindrical feet × ·02909 = cubic yards.
Cubic feet × 6·232 = imperial gallons.
Imperial gallons × ·1604 = cubic feet.
Cubic inches × ·003607 = imperial gallons.
Imperial gallons × 277·3 = cubic inches.
Imperial gallons × 4·541 = litres.
Cubic feet × ·779 = bushels.
Cubic inches × ·00045 = bushels.
Bushels × ·0476 = cubic yards.
Bushels × 1·284 = cubic feet.
Bushels × 2218·2 = cubic inches.
Lineal feet × ·00019 = statute miles.
Lineal yards × ·0006 = statute miles.
Statute miles × ·869 = mean geographical miles.
Mean geographical miles × 1·151 = statute miles.
Pounds avoirdupois × 7000 = grains.

Pounds avoirdupois × ·82286 = pounds troy.
Pounds troy × 1·2153 = pounds avoirdupois.
Grains × ·0001429 = pounds avoirdupois.
Pounds avoirdupois × ·009 = cwts.
Pounds avoirdupois × ·00045 = tons.
Pounds on square inch × 144 = pounds on square foot.
Pounds on square foot × ·007 = pounds on square inch.
Miles per hour × 1·467 = feet per second.
Feet per second × ·682 = miles per hour.
Diameter of circle × 3·1416 = circumference.
Circumference of circle × ·31831 = diameter.
Diameter of circle × ·8862 = side of equal square.
Circumference of circle × ·2821 = side of equal square.
Diameter of circle × ·7071 = side of inscribed square.
Circumference of circle × ·2251 = side of inscribed square.
Area of circle × ·6366 = side of inscribed square.
Side of square × 1·128 = diameter of equal circle.
Side of square × 3·545 = circumference of equal circle.
Side of square × 1·414 = diameter of circumscribing circle.
Side of square × 4·443 = circumference of circumscribing circle.
Square of diameter × ·7854 = area of circle.
Square root of area × 1·12837 = diameter of equal circle.
Square of diameter of sphere × 3·1416 = convex surface.
Cube of diameter of sphere × ·5236 = solidity.
Diameter of sphere × ·806 = dimensions of equal cube.
Diameter of sphere × ·6667 = length of equal cylinder.
One atmosphere = 14·7 pounds on square inch.
" = 2116 pounds on square foot.
" = 29·922 inches of mercury.
" = 33·9 feet of water.

Each 1000 cubic feet of coal gas in a holder × 37 = (approximate) weight of gas in pounds.

The atomic weight of an *elementary* gas × ·0691 = its specific gravity.*

Half the atomic weight of a *compound* gas or vapour × ·0691 = its specific gravity.

* Exceptions to this rule occur in the case of the vapours of phosphorus and arsenic, whose atomic weights must be doubled, and in those of mercury, zinc, and cadmium, the atomic weights of which must be halved.

TABLE OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND SIDES OF EQUAL SQUARES.

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
¼	·7854	·0490	·2215	13¾	43·197	148·489	12·185
½	1·5708	·1963	·4431	14	43·982	153·938	12·406
¾	2·3562	·4417	·6646	14¼	44·767	159·485	12·628
1	3·1416	·7854	·8862	14½	45·553	165·130	12·850
1¼	3·9270	1·2271	1·1077	14¾	46·338	170·873	13·071
1½	4·7124	1·7671	1·3293	15	47·124	176·715	13·293
1¾	5·4978	2·4052	1·5508	15¼	47·909	182·654	13·514
2	6·2832	3·1416	1·7724	15½	48·694	188·692	13·736
2¼	7·0686	3·9760	1·9939	15¾	49·480	194·828	13·957
2½	7·8540	4·9087	2·2155	16	50·265	201·062	14·174
2¾	8·6394	5·9395	2·4370	16¼	51·051	207·394	14·400
3	9·4248	7·0686	2·6586	16½	51·836	213·825	14·622
3¼	10·210	8·2957	2·8801	16¾	52·621	220·353	14·843
3½	10·995	9·6211	3·1017	17	53·407	226·980	15·065
3¾	11·781	11·044	3·3232	17¼	54·192	233·705	15·286
4	12·566	12·566	3·5448	17½	54·978	240·528	15·508
4¼	13·351	14·186	3·7663	17¾	55·763	247·450	15·730
4½	14·137	15·904	3·9880	18	56·548	254·469	15·951
4¾	14·922	17·720	4·2095	18¼	57·334	261·587	16·173
5	15·708	19·635	4·4310	18½	58·119	268·803	16·394
5¼	16·493	21·647	4·6525	18¾	58·905	276·117	16·616
5½	17·278	23·758	4·8741	19	59·690	283·529	16·837
5¾	18·064	25·967	5·0956	19¼	60·475	291·039	17·060
6	18·849	28·274	5·3172	19½	61·261	298·648	17·280
6¼	19·635	30·679	5·5388	19¾	62·046	306·355	17·502
6½	20·420	33·183	5·7603	20	62·832	314·160	17·724
6¾	21·205	35·784	5·9819	20¼	63·617	322·063	17·945
7	21·991	38·484	6·2034	20½	64·402	330·064	18·167
7¼	22·776	41·282	6·4350	20¾	65·188	338·163	18·388
7½	23·562	44·178	6·6465	21	65·973	346·361	18·610
7¾	24·347	47·173	6·8681	21¼	66·759	354·657	18·831
8	25·132	50·265	7·0897	21½	67·544	363·051	19·053
8¼	25·918	53·456	7·3112	21¾	68·329	371·543	19·274
8½	26·703	56·745	7·5328	22	69·115	380·133	19·496
8¾	27·489	60·132	7·7544	22¼	69·900	388·822	19·718
9	28·274	63·617	7·9760	22½	70·686	397·608	19·939
9¼	29·059	67·200	8·1974	22¾	71·471	406·493	20·161
9½	29·845	70·882	8·4190	23	72·256	415·476	20·382
9¾	30·630	74·662	8·6405	23¼	73·042	424·557	20·604
10	31·416	78·540	8·8620	23½	73·827	433·781	20·825
10¼	32·201	82·516	9·0836	23¾	74·613	443·014	21·047
10½	32·986	86·590	9·3051	24	75·398	452·390	21·268
10¾	33·772	90·762	9·5267	24¼	76·183	461·864	21·490
11	34·557	95·033	9·7482	24½	76·969	471·436	21·712
11¼	35·343	99·402	9·9698	24¾	77·754	481·106	21·933
11½	36·128	103·869	10·191	25	78·540	490·875	22·155
11¾	36·913	108·434	10·413	25¼	79·325	500·741	22·376
12	37·699	113·097	10·634	25½	80·110	510·706	22·598
12¼	38·484	117·859	10·856	25¾	80·896	520·769	22·819
12½	39·270	122·718	11·077	26	81·681	530·930	23·041
12¾	40·055	127·676	11·299	26¼	82·467	541·189	23·262
13	40·840	132·732	11·520	26½	83·252	551·547	23·484
13¼	41·626	137·886	11·742	26¾	84·037	562·002	23·706
13½	42·411	143·139	11·963	27	84·823	572·556	23·927

Diam.	Circumference.	Area.	Side of Equal Square.
27¼	85·608	583·208	24·149
27½	86·394	593·958	24·370
27¾	87·179	604·807	24·592
28	87·964	615·753	24·813
28¼	88·750	626·798	25·035
28½	89·535	637·941	25·256
28¾	90·321	649·182	25·478
29	91·106	660·521	25·699
29¼	91·891	671·958	25·921
29½	92·677	683·494	26·143
29¾	93·462	695·128	26·364
30	94·248	706·860	26·586
30¼	95·033	718·690	26·807
30½	95·818	730·618	27·029
30¾	96·604	742·644	27·250
31	97·389	754·769	27·472
31¼	98·175	766·992	27·693
31½	98·960	779·313	27·915
31¾	99·745	791·732	28·136
32	100·531	804·249	28·358
32¼	101·316	816·865	28·580
32½	102·102	829·578	28·801
32¾	102·887	842·390	29·023
33	103·672	855·300	29·244
33¼	104·458	868·308	29·466
33½	105·243	881·415	29·687
33¾	106·029	894·619	29·909
34	106·814	907·922	30·131
34¼	107·599	921·323	30·352
34½	108·385	934·822	30·574
34¾	109·170	948·419	30·795
35	104·956	962·115	31·017
35¼	110·741	975·908	31·238
35½	111·526	989·800	31·460
35¾	112·312	1003·79	31·681
36	113·097	1017·87	31·903
36¼	113·883	1032·06	32·124
36½	114·668	1046·39	32·349
36¾	115·453	1060·73	32·567
37	116·239	1075·21	32·789
37¼	117·024	1089·79	33·011
37½	117·810	1104·46	33·232
37¾	118·595	1119·24	33·454
38	119·380	1134·11	33·675
38¼	120·166	1149·08	33·897
38½	120·951	1164·15	34·118
38¾	121·737	1179·32	34·340
39	122·522	1194·59	34·561
39¼	123·307	1209·95	34·783
39½	124·093	1225·42	35·005
39¾	124·878	1240·98	35·226
40	125·664	1256·64	35·448
40¼	126·449	1272·39	35·669
40½	127·234	1288·25	35·891
40¾	128·020	1304·20	36·112
41	128·805	1320·25	36·334
41¼	129·591	1336·40	36·555
41½	130·376	1352·65	36·777
41¾	131·161	1369·00	36·999
42	131·947	1385·44	37·220
42¼	132·732	1401·98	37·442
42½	133·518	1418·62	37·663
42¾	134·303	1435·36	37·885
43	135·088	1452·20	38·106
43¼	135·874	1469·13	38·328
43½	136·659	1486·17	38·549
43¾	137·445	1503·30	38·771
44	138·230	1520·53	38·993
44¼	139·015	1537·86	39·214
44½	139·801	1555·28	39·436
44¾	140·586	1572·81	39·657
45	141·372	1590·43	39·879
45¼	142·157	1608·15	40·110
45½	142·942	1625·97	40·322
45¾	143·728	1643·89	40·543
46	144·513	1661·90	40·765
46¼	145·299	1680·01	40·986
46½	146·084	1698·23	41·208
46¾	146·869	1716·54	41·429
47	147·655	1734·94	41·651
47¼	148·440	1753·45	41·873
47½	149·226	1772·05	42·094
47¾	150·011	1790·76	42·316
48	150·796	1809·56	42·537
48¼	151·582	1828·46	42·759
48½	152·367	1847·45	42·980
48¾	153·153	1866·55	43·202
49	153·938	1885·74	43·423
49¼	154·723	1905·03	43·645
49½	155·509	1924·42	43·867
49¾	156·294	1943·91	44·088
50	157·080	1963·50	44·310
50¼	157·865	1983·18	44·531
50½	158·650	2002·96	44·753
50¾	159·436	2022·84	44·974
51	160·221	2042·82	45·196
51¼	161·007	2062·90	45·417
51½	161·792	2083·07	45·639
51¾	162·577	2103·35	45·861
52	163·363	2123·72	46·082
52¼	164·148	2144·19	46·304
52½	164·934	2164·75	46·525
52¾	165·719	2185·42	46·747
53	166·504	2206·18	46·968
53¼	167·290	2227·05	47·190
53½	168·075	2248·01	47·411
53¾	168·861	2269·06	47·633
54	169·646	2290·22	47·854
54¼	170·431	2311·48	48·076
54½	171·217	2332·83	48·298
54¾	172·002	2354·28	48·519
55	172·788	2375·83	48·741
55¼	173·573	2397·48	48·962
55½	174·358	2419·22	49·184
55¾	175·144	2441·07	49·405
56	175·929	2463·01	49·627

Diam.	Circumference.	Area.	Side of Equal Square.
56¼	176·715	2485·05	49·848
56½	177·500	2507·19	50·070
56¾	178·285	2529·42	50·291
57	179·071	2551·76	50·513
57¼	179·856	2574·19	50·735
57½	180·642	2596·72	50·956
57¾	181·427	2619·35	51·178
58	182·212	2642·08	51·399
58¼	182·998	2664·91	51·621
58½	183·783	2687·83	51·842
58¾	184·569	2710·85	52·064
59	185·354	2733·97	52·285
59¼	186·139	2757·19	52·507
59½	186·925	2780·51	52·729
59¾	187·710	2803·92	52·950
60	188·496	2827·44	53·172
60¼	189·281	2851·05	53·393
60½	190·066	2874·76	53·615
60¾	190·852	2898·56	53·836
61	191·637	2922·47	54·048
61¼	192·423	2946·47	54·279
61½	193·208	2970·57	54·501
61¾	193·993	2994·77	54·723
62	194·779	3019·07	54·944
62¼	195·564	3043·47	55·166
62½	196·350	3067·96	55·387
62¾	197·135	3092·56	55·609
63	197·920	3117·25	55·830
63¼	198·706	3142·04	56·052
63½	199·491	3166·92	56·273
63¾	200·277	3191·91	56·495
64	201·062	3216·99	56·716
64¼	201·847	3242·17	56·938
64½	202·633	3267·46	57·159
64¾	203·418	3292·83	57·381
65	204·204	3318·31	57·603
65¼	204·989	3343·88	57·824
65½	205·774	3369·56	58·046
65¾	206·560	3395·33	58·267
66	207·345	3421·20	58·489
66¼	208·131	3447·16	58·710
66½	208·916	3473·23	58·932
66¾	209·701	3499·39	59·154
67	210·487	3525·66	59·375
67¼	211·272	3552·01	59·597
67½	212·058	3578·47	59·818
67¾	212·843	3605·03	60·040
68	213·628	3631·68	60·261
68¼	214·414	3658·44	60·483
68½	215·199	3685·29	60·704
68¾	215·985	3712·24	60·926
69	216·770	3739·28	61·147
69¼	217·555	3766·43	61·369
69½	218·341	3793·67	61·591
69¾	219·126	3821·02	61·812
70	219·912	3848·46	62·034
70¼	220·697	3875·99	62·255
70½	221·482	3903·63	62·477
70¾	222·268	3931·36	62·698
71	223·053	3959·20	62·920
71¼	223·839	3987·13	63·141
71½	224·624	4015·16	63·363
71¾	225·409	4043·28	63·545
72	226·195	4071·51	63·806
72¼	226·980	4099·83	64·028
72½	227·766	4128·25	64·249
72¾	228·551	4156·77	64·471
73	229·336	4185·39	64·692
73¼	230·122	4214·11	64·914
73½	230·907	4242·92	65·135
73¾	231·693	4271·83	65·357
74	232·478	4300·85	65·578
74¼	233·263	4329·95	65·800
74½	234·049	4359·16	66·022
74¾	234·834	4388·47	66·243
75	235·620	4417·87	66·465
75¼	236·405	4447·37	66·686
75½	237·190	4476·97	66·908
75¾	237·976	4506·67	67·129
76	238·761	4536·47	67·351
76¼	239·547	4566·36	67·572
76½	240·332	4596·35	67·794
76¾	241·117	4626·44	68·016
77	241·903	4656·63	68·237
77¼	242·688	4686·92	68·459
77½	243·474	4717·30	68·680
77¾	244·259	4747·79	68·902
78	245·044	4778·37	69·123
78¼	245·830	4809·05	69·345
78½	246·615	4839·83	69·566
78¾	247·401	4870·70	69·788
79	248·186	4901·68	70·009
79¼	248·971	4932·75	70·231
79½	249·757	4963·92	70·453
79¾	250·542	4995·19	70·674
80	251·328	5026·56	70·896
80¼	252·113	5058·01	71·119
80½	252·898	5089·58	71·339
80¾	253·684	5121·24	71·562
81	254·469	5153·00	71·782
81¼	255·255	5184·86	72·005
81½	256·040	5216·82	72·225
81¾	256·825	5248·87	72·449
82	257·611	5281·02	72·668
82¼	258·396	5313·27	72·892
82½	259·182	5345·62	73·111
82¾	259·967	5370·07	73·335
83	260·752	5410·62	73·554
83¼	261·538	5443·26	73·778
83½	262·323	5476·00	73·997
83¾	263·109	5508·84	74·221
84	263·894	5541·78	74·440
84¼	264·679	5574·81	74·664
84½	265·465	5607·95	74·884
84¾	266·250	5641·18	75·107
85	267·036	5674·51	75·327
85¼	267·821	5707·94	75·550
85½	268·606	5741·47	75·770

Diam.	Circumference.	Area.	Side of Equal Square.	Diam.	Circumference.	Area.	Side of Equal Square.
85¾	269·392	5775·09	75·994	99¼	311·803	7736·62	87·958
86	270·177	5808·81	76·213	99½	312·589	7775·65	88·179
86¼	270·963	5842·63	76·437	99¾	313·374	7814·79	88·401
86½	271·748	5876·55	76·656	100	314·160	7854·00	88·622
86¾	272·533	5910·57	76·880	100¼	314·945	7893·31	88·844
87	273·319	5944·69	77.099	100½	315·730	7932·73	89·065
87¼	274·104	5978·90	77.323	100¾	316·516	7972·21	89·287
87½	274·890	6013·21	77·542	101	317·301	8011·86	89·508
87¾	275·675	6047·62	77·766	101¼	318·087	8051·57	89·730
88	276·460	6082·13	77·985	101½	318·872	8091·38	89·952
88¼	277·246	6116·74	78·209	101¾	319·657	8131·29	90·173
88½	278·031	6151·44	78·428	102	320·443	8171·30	90·395
88¾	278·817	6186·25	78·652	102¼	321·228	8211·40	90·616
89	279·602	6221·15	78·871	102½	322·014	8251·60	90·838
89¼	280·387	6256·15	79·095	102¾	322·799	8291·86	91·059
89½	281·173	6291·25	79·315	103	323·584	8332·30	91·281
89¾	281·958	6326·44	79·538	103¼	324·370	8372·80	91·502
90	282·744	6361·74	79·758	103½	325·155	8413·40	91·724
90¼	283·529	6397·13	79·982	103¾	325·941	8454·09	91·946
90½	284·314	6432·62	80·201	104	326·726	8494·88	92·167
90¾	285·100	6468·21	80·425	104¼	327·511	8535·77	92·389
91	285·885	6503·89	80·644	104½	328·297	8576·76	92·610
91¼	286·671	6539·68	80·868	104¾	329·082	8617·85	92·832
91½	287·456	6575·56	81·087	105	329·868	8659·03	93·053
91¾	288·241	6611·54	81·311	105¼	330·653	8700·31	93·275
92	289·027	6647·62	81·530	105½	331·438	8741·69	93·496
92¼	289·812	6683·80	81·754	105¾	332·224	8783·17	93·718
92½	290·598	6720·07	81·973	106	333·009	8824·75	93·940
92¾	291·383	6756·45	82·197	106¼	333·794	8866·42	94·161
93	292·168	6792·92	82·416	106½	334·580	8908·20	94·383
93¼	292·954	6829·49	82·640	106¾	335·365	8950·07	94·604
93½	293·739	6866·16	82·859	107	336·151	8992·04	94·826
93¾	294·535	6902·92	83·083	107¼	336·936	9034·11	95·047
94	295·310	6939·79	83·302	107½	337·722	9076·27	95·269
94¼	296·095	6976·75	83·526	107¾	338·506	9118·54	95·491
94½	296·881	7013·81	83·746	108	339·292	9160·90	95·712
94¾	297·666	7050·97	83·970	108¼	340·077	9203·36	95·934
95	298·452	7088·23	84·189	108½	340·863	9245·92	96·155
95¼	299·237	7125·58	84·413	108¾	341·648	9288·58	96·377
95½	300·022	7163·04	84·632	109	342·434	9331·33	96·598
95¾	300·808	7200·59	84·856	109¼	343·219	9374·18	96·820
96	301·593	7238·24	85·077	109½	344·005	9417·14	97·041
96¼	302·379	7275·99	85·299	109¾	344·789	9460·19	97·263
96½	303·164	7313·84	85·520	110	345·576	9503·34	97·485
96¾	303·949	7351·78	85·742	120	376·992	11309·76	106·348
97	304·735	7389·82	85·964	130	408·408	13273·26	115·284
97¼	305·520	7427·96	86·185	140	439·248	15393·84	124·079
97½	306·306	7466·20	86·407	150	471·240	17671·50	132·935
97¾	307·091	7504·54	86·628	160	502·656	20106·24	141·798
98	307·876	7542·98	86·850	170	534·072	22698·06	150·659
98¼	308·662	7581·51	87·071	180	565·488	25446·96	159·521
98½	309·447	7620·14	87·293	190	596·904	28352·94	168·383
98¾	310·233	7658·87	87·514	200	628·320	31416·00	177·247
99	311·018	7697·70	87·736	300	942·480	70686·00	265·869

WEIGHTS AND MEASURES.

Troy Weight.

Pound.		Ounces.		Pennyweights.		Grains.	gr.
				1	=	24	dwt.
		1	=	20	=	480	oz.
1	=	12	=	240	=	5760	lb.

A carat	=	4 grains.
487·5 grs. troy	=	1 oz. avoirdupois.
7000 ,,	=	1 lb. ,,
100 ozs. troy	=	109$\frac{5}{7}$ ozs. avoirdupois.
3·2 grs. troy	=	4 diamond grs.
1 oz. ,,	=	150 ,,

The pound troy is the weight of 22·815 cubic inches of distilled water at the temperature of 62° Fahr., the height of the barometer being 30 inches.

Troy weight is used in philosophical experiments, and in weighing gold, silver, and jewels. The fineness of gold and silver coins means the proportion of the precious metal which they contain. This is expressed in 1000ths of their total weight, or in carats—24ths of their total weight. British gold coins are 22 carats fine, or 0·916$\frac{2}{3}$; silver coins, 0·925. Gold, if pure, is said to be 24 carats fine; if there be one of alloy with 23 carats of pure gold, it is 23 carats fine, and so on downwards. The alloy in gold and silver coins consists of copper. The true weight of a sovereign is 123·274 grains consisting of—pure gold, 11 parts or 113·001 grains; copper, 1 part or 10·273 grains. Silver coin consists of—pure silver, 222 parts; copper, 18 parts. The weight of a shilling is 87$\frac{1}{4}$ grains. 24 pence are made from an avoirdupois pound of copper.

Septem and Decigallon.

The word *septem* (seven) is descriptive of the weight of the 1000th part of a decigallon of distilled water at 62° Fahr., and under a barometric pressure of 30 inches.

A decigallon of water is the tenth part of a gallon, and as a gallon of water at the above temperature and pressure weighs 70,000 grains (10 lb. avoirdupois), it follows that the tenth part, or a decigallon, must weigh 7000 grains (1 lb.).

Each decigallon is divided into 1000 septems; and therefore the septem of pure water weighs 7 grains.

Apothecaries Weight.

				Drams, or Drachms.		Scruples.		Grains.	gr.
						1	=	20	scr.
		Ounces.		1	=	8	=	60	dr.
Pound.		1	=	8	=	24	=	480	oz.
1	=	12	=	96	=	288	=	5760	lb.

The sign of the scruple is ℈ ; the dram, ʒ ; the ounce, ℥.

This weight, which is now abolished, was formerly used for *compounding* medicines. The grain, ounce, and pound are equal to those of troy weight. Drugs are bought and sold by avoirdupois weight.

Avoirdupois Weight.

										Ounces.		Drams.	dr.
								Pounds.		1	=	16	oz.
						Stones.		1	=	16	=	256	lb.
				Quarters.		1	=	14	=	224	=	3584	st.
		Cwts.		1	=	2	=	28	=	448	=	7168	qr.
Ton.		1	=	4	=	8	=	112	=	1792	=	28672	cwt.
1	=	20	=	80	=	160	=	2240	=	35840	=	573440	ton.

1 lb. avoirdupois = 7000 grains troy.

1 oz. avoirdupois = 437·5 grains troy.

100 ozs. avoirdupois = $91\frac{7}{48}$ths ozs. troy.

The imperial pound avoirdupois is the standard unit by means of which all commodities, except gold, silver and precious stones, are weighed, and is equal to the weight of one-tenth of an imperial gallon, or of 27·7274 cubic inches of distilled water at the temperature of 62° Fahr., and when the barometer stands at 30 inches. A certain piece of platinum of this standard weight is kept in the Exchequer Office at Westminster.

Lineal or Long Measure.

										Feet.		Inches.
				Rods, Perches or Poles.				Yards.		1	=	12
								1	=	3	=	36
				Chains.		1	=	$5\frac{1}{2}$	=	$16\frac{1}{2}$	=	198
		Furlongs.		1	=	4	=	22	=	66	=	792
Mile.		1	=	10	=	40	=	220	=	660	=	7920
1	=	8	=	80	=	320	=	1760	=	5280	=	63360

1 link = 7·92 inches.

100 links = 1 chain, or 66 feet, or 22 yards.

1 league = 3 geographical or nautical miles.

1 hand = 4 inches.
1 fathom = 6 feet.
1 military pace = $2\frac{1}{2}$ feet.
1 geometrical pace = 5 feet.
1 geographical or nautical mile = 1·15 statute miles.
1 geographical degree = 60 geographical or nautical miles.
1 Admiralty knot = 6080 feet.

The yard is the imperial standard measure of length, and is the distance, at the temperature of 62° Fahr., between two marks on a certain bar kept in the Exchequer Office, Westminster.

Cloth Measure.

						Nails.		Inches.
				Quarters.		1	=	$2\frac{1}{4}$
		Yards.		1	=	4	=	9
Ell.		1	=	4	=	16	=	36
1	=	$1\frac{1}{4}$	=	5	=	20	=	45

The yard is the same as in long measure, but differs in its divisions and sub-divisions.

Yarn Measure—Cotton.

				Skeins.		Yards.
		Hanks.		1	=	120
Spindle.		1	=	7	=	840
1	=	18	=	126	=	15120

Yarn Measure—Linen.

						Cuts.		Yards.
				Hears.		1	=	300
		Hasps.		1	=	2	=	600
Spindle.		1	=	6	=	12	=	3600
1	=	4	=	24	=	48	=	14400

Square Measure.

								Sq. Feet.		Sq. Inches.
				Sq. Poles or		Sq. Yards.		1	=	144
				Perches.		1	=	9	=	1296
Statute		Sq. Roods.		1	=	$30\frac{1}{4}$	=	$272\frac{1}{4}$	=	39204
Acre.		1	=	40	=	1210	=	10890	=	1568160
1	=	4	=	160	=	4840	=	43560	=	6272640

1 square mile = 640 statute acres.

In round numbers, $\frac{1}{2}$d. per square yard is £10 per statute acre (actually, £10 1s. 8d.).

	4,840	square yards	make 1	statute acre.
Customary Measure.	6150·4	,,	,,	Scotch acre.
	7,840	,,	,,	Irish acre.
	4,000	,,	,,	Devonshire acre.
	4,000	,,	,,	Somersetshire acre.
	5,760	,,	,,	Cornwall acre.
	7,840	,,	,,	Lancashire acre.
	10,240	,,	,,	Cheshire acre.
	10,240	,,	,,	Staffordshire acre.

To Reduce Statute Measure to Customary.

Multiply the number of perches statute measure, by the square feet in a square perch statute measure; divide the product by the square feet in a square perch customary measure, and the quotient will be the answer in square perches *customary*.

To Reduce Customary Measure to Statute.

Multiply the number of perches customary measure, by the square feet in a square perch customary measure; divide the product by the square feet in a square perch statute measure, and the quotient will be the answer in square perches *statute*.

Square Measure—Land.

Acre.		Sq. Roods.		Sq. Chains.		Sq. Perch.		Sq. Links.
						1	=	625
				1	=	..	=	10000
		1	=	2·5	=	..	=	25000
1	=	4	=	10	=	..	=	100000

The chain with which land is measured is 22 yards long.

Solid or Cubic Measure.

Cubic Yard.		Cubic Feet.		Cubic Inches.
		1	=	1728
1	=	27	=	46656

Liquid Measure.

Gallon.		Quarts.		Pints.		Gills.
				1	=	4
		1	=	2	=	8
1	=	4	=	8	=	32

The standard measure of capacity, both for liquids and dry goods, is the imperial gallon, being equal to a volume of distilled water of

277·274 cubic inches, weighing 10 lbs. avoirdupois, at the temperature of 62° Fahr., and 30 inches atmospheric pressure.

Liquid Measures used by Apothecaries.

1 fluid minim = 0·0045 cubic inches. (♏)
60 ,, minims = 1 dram. (ʒ)
8 drams = 1 oz. (℥)
20 ozs. = 1 pint. (⊙)

Wine Measure.

Tun.	Pipes.	Punch.	Hhds.	Tierces.	Gallons.	Quarts.	Pints.
						1	2
					1	4	8
				1	42	168	336
			1	1½	63	252	504
		1	1⅓	2	84	336	672
	1	1½	2	3	126	504	1008
1	2	3	4	6	252	1008	2016

Ale and Beer Measure.

Butt.	Punch.	Hhds.	Barrels.	Kildkns.	Firkins.	Gallons.	Quarts.	Pints.
							1	2
						1	4	8
					1	9	36	72
				1	2	18	72	144
			1	2	4	36	144	288
		1	1½	3	6	54	216	432
	1	1⅓	2	4	8	72	288	576
1	1½	2	3	6	12	108	432	864

Dry Measure.

Last.	Loads or Weys.	Quarters.	Bushels.	Pecks.	Gallons.	Pints.
					1	8
				1	2	16
			1	4	8	64
		1	8	32	64	512
	1	5	40	160	320	2560
1	2	10	80	320	640	5120

3 bushels = 1 sack = 3·85 cubic feet.
12 sacks = 1 chaldron = 46·2 cubic feet.

The imperial bushel contains 80 lbs. avoirdupois of distilled water, and its content is 2218·192 cubic inches, or 1·283 cubic feet.

Table of Time.

Week.		Days.		Hours.		Minutes.		Seconds.
						1	=	60
				1	=	60	=	3600
		1	=	24	=	1440	=	86400
1	=	7	=	168	=	10080	=	604800

28 days = 1 lunar month.
28, 29, 30, or 31 days = 1 calendar month.
1 common year = 365 days, or 52 weeks 1 day.
1 leap year = 366 days, or 52 weeks 2 days.
1 Julian year = 365 days 6 hours.
1 solar year = 365 days 5 hours 48 minutes 49 seconds.
30 degrees = 1 sign.
12 signs = 1 circle of the zodiac.

CIRCULAR AND ANGULAR SPACE.

60″ (seconds)	= 1′ (minute).	60°	= 1 sextant.
60′	= 1° (degree).	90°	= { 1 quadrant. 1 right angle.
30°	= 1 sign	360°	= A circle.
45°	= 1 octant.		

The earth moves through 360° in 24 hours, therefore 15° = 1 hour, and 1° = 4 minutes.

TIME IN WHICH ANY SUM DOUBLES ITSELF, AT RATES OF INTEREST BOTH SIMPLE AND COMPOUND.

Rate of Interest per cent.	Years in which the sum is doubled, at		Rate of Interest per cent.	Years in which the sum is doubled, at	
	Simple Interest.	Compound Interest.		Simple Interest.	Compound Interest.
1	100	69·6608	5	20	14·2067
2	50	35·0028	6	16⅔	11·8957
2½	40	28·0701	7	14²⁄₇	10·2448
3	33⅓	23·4498	8	12½	9·00646
3½	28⁴⁄₇	20·1488	9	11⅑	8·04323
4	25	17·67303	10	10	7·27254
4½	22²⁄₉	15·7473	11	9¹⁄₁₁	6·64189
			12	8⅓	6·11626

FRENCH WEIGHTS AND MEASURES—DECIMAL SYSTEM.

Weights.

French.				English.	
Milligramme	= $\frac{1}{1000}$ or ·001	gramme	=	0·01543	grains.
Centigramme	= $\frac{1}{100}$ or ·01	,,	=	0·1543	,,
Décigramme	= $\frac{1}{10}$ or ·1	,,	=	1·5432	,,
GRAMME	= 1	,,	=	15·432349	,,
				0·643	dwt.
				0·03215	oz. troy.
				0·03527	oz. avoir.
				0·0022	lb.
				0·0000197	cwt.
Décagramme	= 10	grammes	=	154·32	grains.
				0·3527	oz. avoir.
				0·022	lb. ,,
Hectogramme	= 100	,,	=	1,543·23	grains.
				3·527	ozs. avoir.
				0·22046	lb. ,,
Kilogramme	= 1,000	,,	=	15,432·349	grains.
				32·15	ozs. troy.
				35·2739	,, avoir.
				2·2046	lbs.
				2·679	,, troy.
				0·01968	cwt.
				0·00098	ton.
Myriagramme	= 10,000	,,	=	22·046	lbs. avoir.
				0·1968	cwt.
				0·00984	ton.

Quintal = 100,000 grammes = 220·46 lbs. or 1 cwt. 3 qrs. 24½ lbs.

Millier or bar = 1,000,000 ,, = 2,204·62 lbs. or 19 cwt. 2 qrs. 20¾ lbs.

The Gramme is the unit of measures of weight, and is the weight of a cubic centimètre of distilled water at its maximum density (39° Fahr.) *in vacuo*, at sea level in the latitude of Paris, barometer 29·922 inches.

English.		French.	
Grain	=	0·064799	grammes.
Dwt..	=	1·555	"
Dram	=	1·771846	"
Ounce, troy	=	31·1035	"
Ounce, avoirdupois	=	28·3496	"
Pound "	=	453·59	"
		0·454	kilogramme.
Pound, troy	=	373·226	grammes.
		0·373226	kilogrammes.
Cwt.	=	50·8	"
Ton	=	1,016·05	"
		1·01605	tonnes.
		1 tonne × ·984.	

Lineal or Long Measure.

French.			English.	
Millimètre	= $\frac{1}{1000}$ or ·001 mètre .	=	0·03937	inch.
			0·00328	foot.
			0·00109	yard.
Centimètre	= $\frac{1}{100}$ or ·01 " .	=	0·3937	inch.
			0·0328	foot.
			0·0109	yard.
Décimètre	= $\frac{1}{10}$ or ·1 " .	=	3·9371	inches.
			0·3281	foot.
			0·1093	yard.
Metre	= 1 " .	=	39·37079	inches.
			3·2808992	feet.
			1·093633056	yards.
			0·00062	mile.
Décamètre	= 10 mètres .	=	393·7079	inches.
			32·809	feet.
			10·936	yards.
			0·0062	mile.
Hectomètre	= 100 " .	=	3,937·079	inches.
			328·09	feet.
			109·36	yards.
			0·06214	mile.

French.		English.	
Kilomètre =	1,000 mètres . =	39,370·79	inches.
		3,280·9	feet.
		1,093·63	yards.
		0·62138	mile.
Myriamètre =	10,000 „ . =	393,707·9	inches.
		32,809·0	feet.
		10,936·3	yards.
		6·21382	miles.
Ligne or line	. . . . =	0·088819	inch.
Pouce or inch = 12 lines	. . . . . =	1·06583	inches.
Pied or foot = 12 pouces	. . . . =	12·78996	„
Toise = 6 French feet	. . . . . . =	76·74	„

The Mètre is the unit of lineal measure, and is the 10 millionth part of 90° of the meridian.

English.	French.	
Inch . . . . =	25·39954	millimètres.
	2·54	centimètres.
	0·254	décimètre.
	0·0254	mètre.
Foot . . . . =	0·3048	„
Yard . . . . =	0·9144	„
Fathom . . . . =	1·8287	mètres.
Pole . . . . =	5·0291	„
Chain . . . . =	20·116	„
Furlong . . . . =	201·16	„
	0·20116	kilomètre.
Mile . . . . =	1,609·315	mètres.
	1·609315	kilomètres.

Square Measure.

French.		English.	
Milliare	= $\frac{1}{1000}$ or ·001 are or sq. décamètre. =	155·00	sq. ins.
		1·0764	„ feet.
		0·1196	„ yard.
Centiare or sq. mètre.	= $\frac{1}{100}$ or ·01 sq. décamètre . . =	1,550·0	„ ins.
		10·764	„ feet.
		1·196033292	„ yards.
		0·03954	„ perch.
		0·00099	„ rood.
		0·00025	„ acre.

French.		English.	
Déciare	= $\frac{1}{10}$ or ·1 sq. décamètre . . . =	15,501·0	sq. ins.
		107·64	,, feet.
		11·96088	,, yards.
		0·3954	,, perch
		0·0099	,, rood.
		0·0025	,, acre.
Are or sq. décamètre.	= 1 sq. décamètre. =	1,076·4	,, feet.
		119·6068	,, yards.
		3·954	,, prchs.
		0·099	,, rood.
		0·0247	,, acre.
Décare	= 10 ares or sq. décamètres . . =	1,196·088	,, yards.
		39·54	,, prchs.
		0·99	,, rood.
		0·2471	,, acre.
Hectare	= 100 ares or sq. décamètres . . =	11,960·3	,, yards.
		395·4	,, prchs.
		9·89	,, roods.
		2·4712	,, acres.

The are, which is a square décamètre, is the unit of square measure.

English.		French.	
Square inch	=	645·187	sq. millimètres.
		0·000645	,, mètre.
Square foot	=	0·0929	,, ,,
Square yard	=	0·8361	,, ,,
Square perch	=	25·292	,, mètres.
Square rood	=	1,011·7	,, ,,
Square acre	=	4,046·7	,, ,,
Square mile	=	2·59	,, kilomètres.

Solid Measure.

French.		English.	
Millistère	= $\frac{1}{1000}$ or ·001 stère or cubic mètre . =	61·028	cubic inches.
		0·035317	,, foot.
Centistère	= $\frac{1}{100}$ or ·01 stère or cubic mètre . =	610·28	,, inches.
		0·35317	,, foot.

French.			English.	
Décistère	= $\frac{1}{10}$ or ·1 stère or cubic mètre .	=	6,102·8	cubic inches.
			3·5317	„ feet.
			0·1308	„ yard.
Stère or cubic mètre	= 1 stère or cubic mètre . . .	=	61,028·0	„ inches.
			35·317	„ feet.
			1·308	„ yards.
Décastère	= 10 stères or cubic mètres	=	353·17	„ feet.
			13·0802	„ yards.
Hectostère	= 100 „	=	3,531·7	„ feet.
			130·802	„ yards.
Kilostère	= 1,000 „	=	35,317·0	„ feet.
			1,308·02	„ yards.
Myriastère	= 10,000 „	=	13,080·224	„ „

The Stère, which is a cubic mètre, is the unit of solid measure.

English.		French.	
Cubic inch . .	=	0·000016386	stère or cubic mètre
		16,386·0	cubic millimètres.
Cubic foot . .	=	0·028315	stère or cubic mètre.
1,000 cubic feet	=	28·315	stères or cubic mètres.
Cubic yard . .	=	0·7645131	stère or cubic mètre.

Dry and Fluid Measure (*Capacity.*)

French.			English.	
Millilitre	= $\frac{1}{1000}$ or ·001 litre or cubic décimètre	=	0·0610	cubic inch.
			0·00022	imperial bushel.
Centilitre	= $\frac{1}{100}$ or ·01 litre or cubic décimètre .	=	0·61028	cubic inch.
			0·0022	imperial bushel.
Décilitre	= $\frac{1}{10}$ or ·1 litre or cubic décimètre .	=	6·1028	cubic inches.
			0·022	imperial bushel.
Litre or cubic décimètre	= 1 litre or cubic décimètre . . .	=	61·028	cubic inches.
			0·0353	„ foot.
			1·76172	imperial pints.
			0·220215	„ gallon.
			0·0275	„ bushel.
Décalitre	= 10 litres or cubic décimètres. . .	=	610·28	cubic inches.
			0·353	„ foot.
			2·2	imperial gallons.
			0·276	„ bushel.

French.				English.	
Hectolitre	=	100 litres or cubic décimètres . . .	=	6,102·8	cubic inches.
				3·53171	,, feet.
				22·0	imperial gallons.
				2·751	,, bushels.
Kilolitre	=	1,000 litres or cubic décimètres .	=	35·3171	cubic feet.
				220·02	imperial gallons.
				27·512	,, bushels.
Myrialitre	=	10,000 litres or cubic décimètres .	=	353·171	,, cubic feet.
				2,202·15	imperial gallons.
				275·121	,, bushels.

The Litre, which is a cubic décimètre, is the unit of measures of capacity.

English.		French.	
Cubic inch	=	0·016386	litre.
Cubic foot	=	28·315	litres.
1,000 cubic feet.	=	28,315·0	,,
Imperial pint	=	0·5676	litre.
Imperial gallon	=	4·541	litres.
Imperial bushel	=	36·328	,,

MONEY TABLES.

France.

Name.				English Value.
Centime			=	$\frac{19}{200}$ or ·095d.
Franc	=	100 centimes	=	$9\frac{1}{2}$d.
Sou	=	5 ,, ...	=	$\frac{19}{40}$ or ·475d.
Napoléon	=	20 francs	=	15s. 10d.

Accounts are kept in francs and centimes. For convenience in reckoning, a sou may be taken as equal to $\frac{1}{2}$d., a franc as 10d., and 25 francs as 20s.

Belgium.

The Belgian currency is in centimes and francs, having the same English money value as those of France.

To convert centimes per cubic mètre into pence per 1,000 *cubic feet, and vice versâ.*

Centimes per cubic metre × 2·7 = pence per 1,000 cubic feet.
Pence per 1,000 cubic feet × ·37 = centimes per cubic metre.

To convert centimes per litre into pence per 1,000 *cubic feet, and vice versâ.*

Centimes per litre × 2,700 = pence per 1,000 cubic feet.
Pence per 1,000 cubic feet × ·00037 = centimes per litre.

UNITED STATES OF AMERICA.

Name.		English Value.
Cent.	=	½d.
Dollar = 100 cents	=	4s. 2d.
4⅘, or 4·8 dollars, or 4 dollars 80 cents . .	=	£1
Dollars × ·2084	=	£1

To convert dollars and cents per 1,000 *cubic feet into pence per* 1,000 *cubic feet, and vice versâ.*

Dollars and cents per 1,000 cubic feet × 50 = pence per 1,000 cubic feet.

Pence per 1,000 cubic feet × ·02 = dollars and cents per 1,000 cubic feet.

TABLE.

Foreign and Colonial Equivalents of English Money.
(Actual or Approximate.)

Country.	Pound Sterling, Equal to,—	Shilling, Equal to,—	Penny, Equal to,—
Argentine Republic	10 Patacon or Dollars	50 Centimos . . .	4 Centimos.
Austria	10½ Florins	½ Florin, or 50 Kreutzers .	4 Kreutzers.
Belgium.	25 Francs . . .	1¼ Francs . . .	10 Centimes.
Bolivia	7 Dollars . . .	36 Centenas . .	3 Centenas.
Brazil	10 Milreis . . .	½ Milreis or 500 Reis . . .	40 Reis.
Canada	4⅚ Dollars . . .	25 Cents. . . .	2 Cents.
Chili	5¼ Pesos	25 Centavos . .	2 Centavos.
China	5 Dollars, or 3½ Taels, or 35 Mace . .	25 Cents, or 1¾ Mace . . .	2 Cents, or 1⅛ Candareen.
Columbia	5 Pesos. . . .	25 Centavos . .	2 Centavos.
Denmark	20 Krona . . .	1 Krona . . .	8⅓ Ore.
Ecuador	5 Pesos. . . .	25 Centavos. . .	2 Centavos.
Egypt	100 Piastres . . .	5 Piastres . . .	½ Piastre, or 20 Paras.
Finland.	25 Marks . . .	1¼ Marks . . .	10 Penni.
France	25 Francs . . .	1¼ Francs . . .	10 Centimes.
German Empire .	20 Marks . . .	1 Mark or 100 Pfennig . .	8⅓ Pfennig.
Greece	25 Drachmæ . .	1¼ Drachmæ . .	10 Lepta.
Holland	12 Florins . . .	60 Cents. . . .	5 Cents.
Hungary	10¼ Florins . . .	½ Florin, or 50 Kreutzers. .	4 Kreutzers.
India.	10 Rupees and 4 Annas . .	9 Annas . . .	8 Pies.
Italy	25 Lira	1¼ Lira	10 Centesimi.
Japan	5 Yen	25 Sen	2 Sen.
Java	12 Florins . . .	60 Cents. . . .	5 Cents.
Malta	12 Scudi. . . .	7 Tari, 4 Grani .	12 Grani.
Mexico	5 Pesos or 5 Dols.	25 Centavos . .	2 Centavos.
Norway.	20 Krona . . .	1 Krona . . .	8⅓ Ore.
Paraguay	6⅓ Dollars . . .	36 Centena . . .	3 Centena.
Persia	2½ Toman . . .	12 Shahis . . .	1 Shahi.
Peru	5 Sol	2¼ Dineros . . .	2 Centos.
Portugal	5 Milreis . . .	2¼ Testoes . . .	20 Reis.
Russia	6¼ Silver Roubles	48 Copecks . . .	4 Copecks.
Spain.	26 Pesetas . . .	1¼ Pesetas . . .	10 Centimos.
Sweden	20 Krona . . .	1 Krona . . .	8⅓ Ore.
Switzerland . . .	25 Francs . . .	1¼ Francs . . .	10 Centimes.
Tunis	40 Piastres . . .	2 Piastres . . .	
Turkey	120 Piastres . . .	6 Piastres . . .	½ Piastre, or 20 Paras.
United States. . .	4⅚ Dollars . . .	25 Cents. . . .	2 Cents.
Uruguay	5 Pesos	25 Centavos . .	2 Centavos.
Venezuela	5 Pesos	25 Centavos. . .	2 Centavos.

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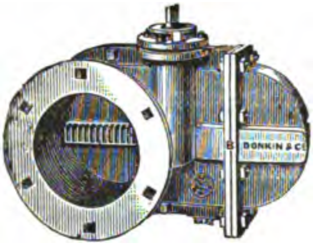

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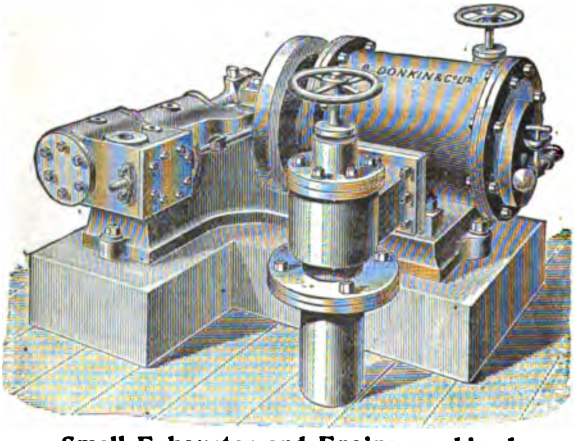

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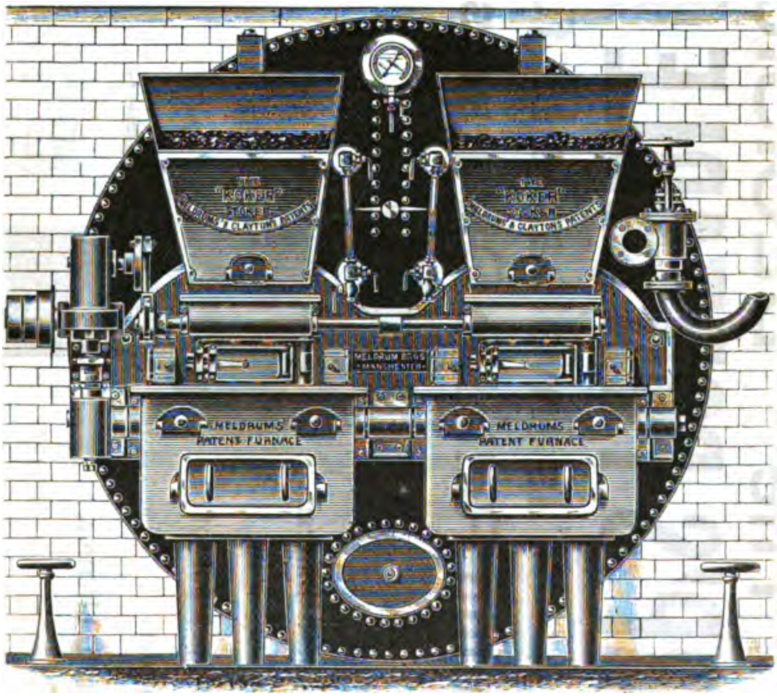

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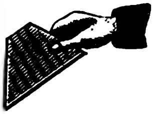

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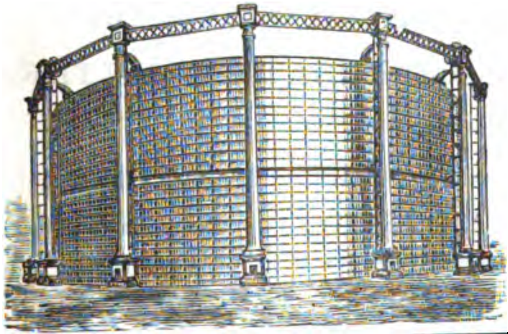

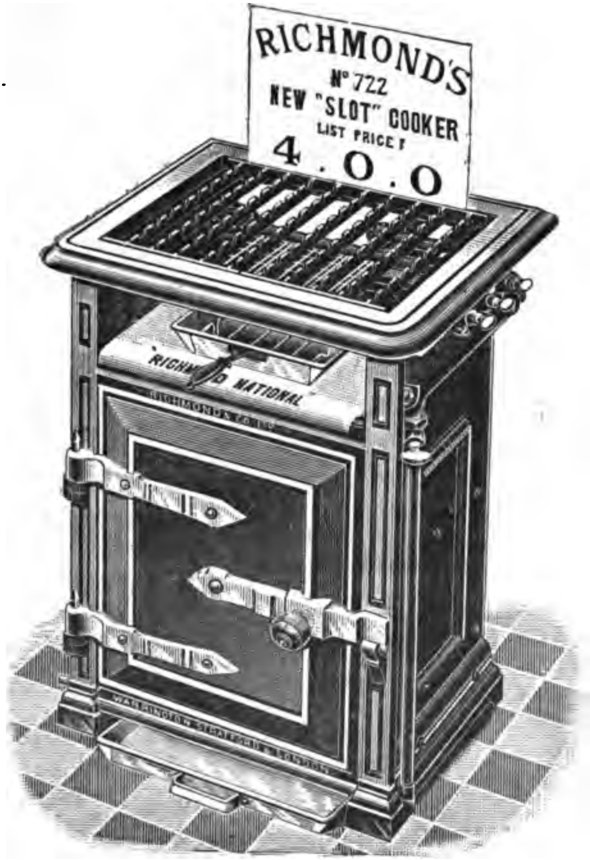
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